COMPETE

Analysis of the contribution of transport policies to the competitiveness of the EU economy and comparison with the United States

Final report

Annex 02a

Background information to Chapter 3: Studies, harmonised approach and panorama of congestion in Europe and the US

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Co-ordinator:

ISI
Fraunhofer Institute Systems and Innovation Research, Karlsruhe, Germany

Partners:

INFRAS
INFRAS
Zurich, Switzerland

TIS
Transport, Innovation and Systems
Lisbon, Portugal

EE
Europe Economics
London, United Kingdom

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Authors:	Claus Doll, Markus Maibach
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	TIS - Transport, Innovation and Systems, Lisbon, Portugal.
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Annex 2: Background information to Chapter 3

1 Introduction

This document contains additional and more detailed material to the COMPETE final report, Chapter 3: "Congestion in Europe and the US". In particular the single sections provide the following information:

- Chapter 2: "**Methodological aspects**" very briefly introduces the context of information acquisition and processing to derive the Panorama of Congestion for Europe and the US and to draw conclusions on an appropriate harmonised approach of congestion monitoring for Europe.
- Chapter 3: "R**eview of studies and applied approaches in road and rail**" gives an overview of methodologies and results of several national and international studies on congestion in road and rail transport. The chapter also reviews national practices to monitor and present traffic congestion trends.
- Chapter 4: "**International trends in road and rail transport**" focuses on evidence on delay and congestion estimates on an international scale based on existing studies. The chapter thus complements the review in Chapter 3 by compiled data sets on a wider geographical scope.
- Chapter 5: "**Case Study European and US air transport**" particularly concentrates on statistical information and the analysis of airport capacity in the European and US air transport markets. Specific analyses on the capacity situation are presented for the top-5 airports in Europe and in the US.
- Chapter 6: "**Case Study on European and US Seaports**" then specifically looks into the problem of seaport congestion by investigating 20 ports across the US and Europe. The analyses are based on expert interviews with entities related to shipping and port handling as well as by a literature overview.
- Chapter 7: "**Synthesis of the COMPETE country reviews**" systematically summarises one of the core elements of the COMPETE work, which is the investigation of congestion measurement, status and perspectives of all modes in the 25 EU Member States, Switzerland and the US. The chapter consists of a set of modal overview tables aiming summarising the country reviews presented by Annex 3 to the COMPETE final report. These results constitute the "Panorama of Congestion" derived by the study.
- Chapter 8: "**Towards a harmonised approach for Europe**" provides concepts and derivations of a harmonised approach for monitoring congestion in Europe. The chapter does not contain all information provided by the respective section 3.4 in the COMPETE Final Report and thus is to be considered as a set of additional thoughts and arguments towards the conclusions drawn.

2 Methodological aspects

2.1 The COMPETE congestion literature database

The COMPETE study covers a great number of countries, case studies and transport modes. Moreover, the available literature is extremely heterogeneous, ranging from technical reports on the measurement of network conditions, over economic studies of costs and impacts to policy papers of governmental and lobby organisations. In order to structure the process of reviewing and analysing the literature, in Task 3 a literature database was developed storing the following details:

- bibliographical data
- coverage of transport modes
- time frame
- type of information contained
- short summary

Figure 2-1 presents a screen shot of the user interface of the literature database.

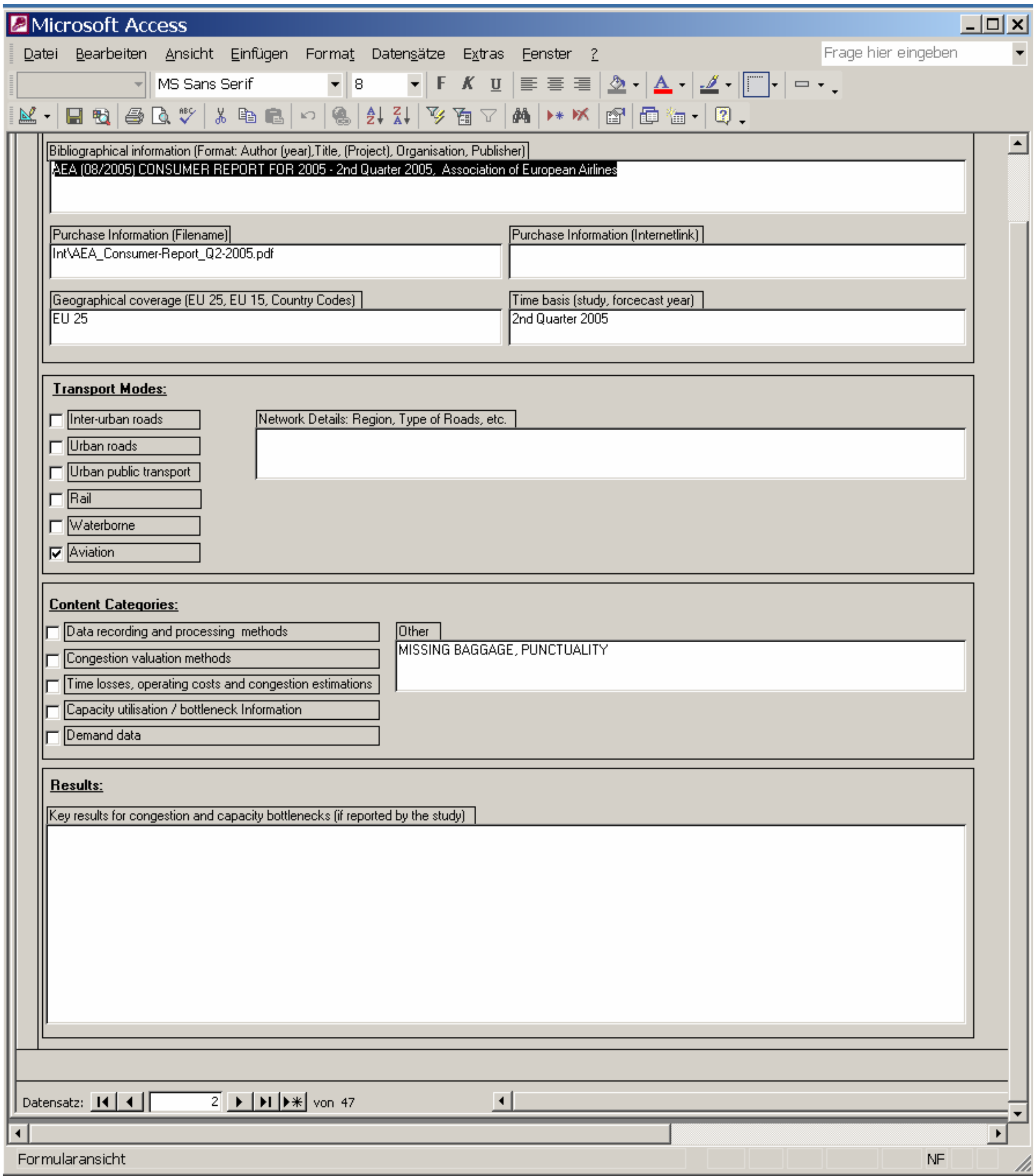


Figure 2-1: Screenshot of the COMPETE congestion literature database

The database was filled throughout the course of the study in order to allow a comfortable search across the various sources found. Currently it contains more than 300 documents across various countries. Together with the database the documents will be delivered to the EC in PDF form on DVD as far as available.

The contents of the database are presented in the appendix to this annex report.

2.2 Interviews

The literature survey was accompanied by a set of interviews with key persons and / or institutions in the field of research, management and policy-making. For this purpose a questionnaire was developed in two variants:

- a long version containing 21 questions,
- a short version containing 12 questions and
- a brief version consisting of 4 questions

The questionnaires are provided in Chapter 30 of Annex 3 to the COMPETE final report. They are either distributed by e-mail or by surface mail. The EC provided a covering letter in order to encourage the interview partners to co-operate. The responses collected by the different countries so far are contained as additional information in the annex to this interim report.

The reply rate to the questionnaires sent out by project partners has been rather low. Across the research team the following reasons have been identified:

- Length of the Questionnaire: Even the short version consisting of 12 questions is perceived to be too long by most interviewees and the complexity of the questions requires too much survey activities. Accordingly, the brief version was distributed in a later stage of the project.
- Structure of the questionnaire: The questions go across the modes of transport and across various aspects of data collection, economic assessment, use of the result and policy plans. These can usually not be answered by a single person and thus the questionnaire has to go through different departments of an organisation.
- The general willingness of interview partners to co-operate by answering the questionnaire appears to be low.
- The questionnaire has been designed to serve all modes and different activity fields of potential interview partners. Thus it is not adopted to the specific interests of institutions or companies, which reduces their interest in answering it.

Nevertheless, the country reports presented in Annex 3 to the COMPETE final report have managed to receive valuable information from multiple interview partners.

3 Review of studies and applied approaches in road and rail transport

In the course of the COMPETE study an extensive literature review on national and international studies on the issue of congestion has been carried out. Besides rail and aviation statistics and an assessment of scheduled transport delays in the UNITE project all studies reviewed have been on inter-urban and / or on urban road transport. Accordingly, the subsequent chapters are grouped along this line. However, it must be mentioned that some studies deal with urban and inter-urban congestion simultaneously. These studies have been allocated to the inter-urban part.

3.1 Inter-urban road and all network studies

3.1.1 The UNITE Project

The UNITE study (Nash et al. 2003) was carried out between 2000 and 2002 under the co-ordination of the Institute for Transport Studies, Leeds on behalf of DG-TREN. It aimed at establishing accounts on transport costs for 18 European countries (EU15 plus Switzerland, Hungary and Estonia) and to carry out roughly 30 case studies on marginal external costs. The cost categories included in the analyses were infrastructure, operation, user costs and benefits, accidents, air emissions, noise and impacts on nature and landscape. Congestion was on part of the user costs and benefit category, which was completed by the analysis of the positive effects of density, the so-called Mohring effect. The case studies and the country accounts have covered all modes (road, rail, air, inland navigation and sea shipping). Accounts were generated for the years 1996, 1998 and 2005.

In the country accounts, total congestion has been assessed on the basis of delay costs including time costs and wasted fuel. There was no explicit distinction between recurrent and non-recurring congestion, but most of the countries which have computed congestion costs have considered all delays. In road transport a reference speed equalling the average travel speed by road class was recommended, whereas the delay margins proposed in scheduled transport were 5 minutes for rail passenger and 15 minutes for rail freight, 60 minutes for shipping and 15 minutes for aviation. The values of time were assembled from different studies in the Netherlands, the UK and Scandinavia. The results are presented in Table 3-1.

Table 3-1: Values of Travel Time according to the UNITE study

Transport segment	HCG 1994 UK 1994	HCG 1998 NL 1997	SIKA 1997 SE 1996	EUNET 2000 EU 1995	UNITE 2002 EU 1998	TC 2006 Canada 1993
Passenger transport - VOT per person-hour						
Car / motorcycle		6.70	9.31			
Business	21.23	21.00	11.95		21.00	20.00
Commuting / private	5.53	6.37	3.91		6.00	
leisure / holiday	3.79	5.08	3.10		4.00	5.70
Coach (Inter-urban)			7.47			
Business	21.23				21.00	
Commuting / private	5.95		5.40		6.00	
leisure / holiday	3.08		4.37		4.00	
Urban bus / tramway			5.75			
Business	21.23				21.00	
Commuting / private	5.95		4.94		6.00	
leisure / holiday	3.08		3.22		3.20	
Inter-urban rail		4.97	8.50			
Business		18.43	11.95		16.00	
Commuting / private		6.48	6.21		6.40	
leisure / holiday		4.41	4.94		4.70	
Air traffic				40.60		
Business			16.20		16.20	
Commuting / private			10.11		10.00	
leisure / holiday			10.11		10.00	
Freight Transport - VOT per vehicle, train, wagon, ship and ton-hour						
Road Transport	36.00				32.60	
LDV	45.00		39.68	30.75	40.76	
HDV	48.00		39.68	30.75	43.47	
Rail transport						
Full trainload	801.00			645.37	725.45	
Wagon load	32.00			26.16	28.98	
Average per ton	0.83				0.76	
Inland navigation						
Full ship load	222.00			178.55	201.06	
Average per ton	0.20				0.18	
Maritime shipping						
Full ship load	222.00			178.55	201.06	
Average per ton	0.20				0.18	

Source: Link et al. (2002), Transport Canada (2006)

The results of the country accounts in terms of total annual congestion costs in 1998 are presented in Table 3-2. However it should be mentioned, that due to data availability at the single countries the results are not comparable. In particular the networks included differ and the recommended reference travel speed was not in all cases applied.

Across all available country accounts road congestion amounts to roughly 1.1% of GDP and in most cases ranges between 1 and 3 €-ct. per vehicle kilometre. Exceptions are the UK and Greece where average costs around 4 €-ct./vkm have been calculated. The difference can be explained as these countries have explicitly addressed urban congestion, while most other countries have shown motorway congestion only. For rail and air delays only total figures are available.

Table 3-2: Country results of the UNITE accounts 1998

Country	UNITE country results 1998 (million Euro 1998)				
	Road and PT			Rail	Air
	mill. €	% of GDP	€ / vkm	mill. €	mill. €
Austria	1,555	0.8195	0.0263	25	57
Belgium		:	:	32	
Denmark	407	0.2791	0.0095	9	119
Finland	:	:	:		
France	17,293	1.3245	0.0330	133	1.090
Germany	17,381	0.9044	0.0277	682	147
Greece	5,192	4.8364	0.0310	36	47
Hungary	792	1.8635	0.0410		
Ireland	401	0.5208	0.0105		
Italy	:	:	:		
Luxemburg	:	:	:		
Netherlands	3,103	0.8810	0.0263	45	89
Portugal	121[1]	0.1222[1]	0.0020[1]		8
Spain	3,312	0.6804	0.0174	10	249
Sweden		:	:	63	21
Switzerland	587	0.2502	0.0106	65	132
UK	19.371	1.5509	0.0422	185	581
TOTAL	69,515	1.1191			
Notes: 1): for Lisbon only					

Source: Data from Nash et al. (2003)

The marginal cost case studies aimed at determining the average marginal external congestion costs in inter-urban road transport along four trans-European corridors, for five cities, for Madrid airport and for Swedish seaports.

The road case studies have applied standard speed-flow diagrams from the German road assessment manual EWS (FGSV 1997) to the VACLAV European transport network database containing UN and national traffic count information and model results. The urban case studies have applied the traffic model SATURN, where the Brussels model was set up independently from the other urban cases (Edinburgh, Salzburg and Helsinki).

Table 3-3: UNITE road case studies: Average marginal congestion costs

Average optimal congestion costs along inter-urban corridors, (Case Studies 7A - 7D) Departure time: 8:00 a.m.			Average congestion costs in several urban road networks (Case Studies 7E, 7F), Morning peak traffic		
	€-ct./vkm	€-ct/pkm,tkm[1]		€-ct./vkm	€-ct./ pkm [2]
7A: Paris - Brussels (car)	4.2	3.0	7E: Brussels [3]	25.2	21.0
7B: Paris - Munich (car)	2.8	2.0	7F: Edinburgh	11.6	9.7
7C: Cologne - Milan (HGV)	8.5	0.72	7F: Salzburg	16.4	16.7
7D: Duisburg - Mannheim (HGV)	12.5	1.06	7F: Helsinki	5.2	4.3

[1] using a occupancy factor of 1,4 for passenger cars and 11,8t for HGV s
[2] using a vehicle occupancy factor of 1,2
[3] Original model output with VOT=4.30 € / PCU-h: 0.09 € / PCU-km

Source: UNITE Deliverable D7 (Doll 2002)

The authors point out that in particular the urban cases are not comparable to each other as the prevailing geographical conditions of the urban networks as well as the detail of the network representation within the models differs. These differences impact the case study results to a large degree.

The non-road case studies have applied several methodologies to approach the marginal costs of congestion. For Swiss railways and Madrid airport macro-economic analyses of demand and delay data have been carried out, while the UK rail and the Swedish seaport case studies have used microscopic data on train delays and vessel wait and service times. The magnitude of results is presented in Table 3-3.

Table 3-4: UNITE scheduled transport case studies: Average marginal congestion costs

Case Study	€ / trip		€-ct / pkm		€-ct./ vkm	
	Low	High	Low	High	Low	High
7AB: Swiss railways	0.07 [1]	0.095 [2]	0.074 [1]	0.28 [2]	3.7 [1]	41.9 [2]
Appendix I: UK railways	0.28 [3]	0.075 [4]	0.280 [3]	0.29 [4]	14.0 [3]	44.0 [4]
7I: Madrid airport	27.65 [5]		9.22 [5]		1189 *5)	
5G: Swedish seaports	0		0		0	

[1] Off-peak traffic: Travel distance 100 km, occupancy: 50 passengers. - [2] Peak traffic: Travel distance 35 km, train occupancy: 150 passengers. - [3] London commuter train: Travel distance 100 km, occupancy: 50 passengers.- [4] Regional train: Travel distance 35 km, train occupancy: 150 passengers. - [5] Monthly average: Flight distance: 300 km, plane occupancy: 130 passengers.

Source: UNITE Deliverable D7 (Doll 2002)

The UNITE results reveal, that the sophisticated computation of marginal external congestion costs in scheduled transport is rather demanding. Due to the network effects occurring, due to the strong influence of service operations practices and due to the high share of non-congestion related delays there are even theoretical limitations to the application of this principle to scheduled services.

3.1.2 External Costs of Transport 2000 and 2004

A comprehensive picture of road congestion costs using the economic and the engineering approach based on transport model applications is given by Maibach et al. (2004) for the EU15 plus Switzerland and Norway. Based on the VACLAV transport network and demand database the study has computed three measures of congestion: (1) the deadweight loss according to neoclassical theory, which represents the economic benefit achieved by marginal social cost pricing (MSCP) of congestion externalities, (2) additional time and fuel costs compared to a road-type specific reference speed and (3) the revenues expected from applying MSCP on all roads. Key results are:

- Total costs presented in Figure 3-1 show the clear dominance of the big countries Germany, France, UK and Italy.
- Given the high reference speed used in the studies (120 kph on motorways and 60 kph on trunk roads), the delay costs add up to a considerable amount.
- Comparing the deadweight loss with the associated revenues it gets obvious that the amount of money which has to be moved is roughly ten times higher than the social benefit which can be expected from MSCP. This implies that transaction costs, which usually range between 5% (ASFINAG, Austria) up to 20% (Toll Collect, Germany) may well eat up the entire potential benefit from road charging.

For policy implementation the latter result implies that congestion charging should be efficient in two ways: Low transaction costs of the payment system and concentration on network parts suffering from congestion.

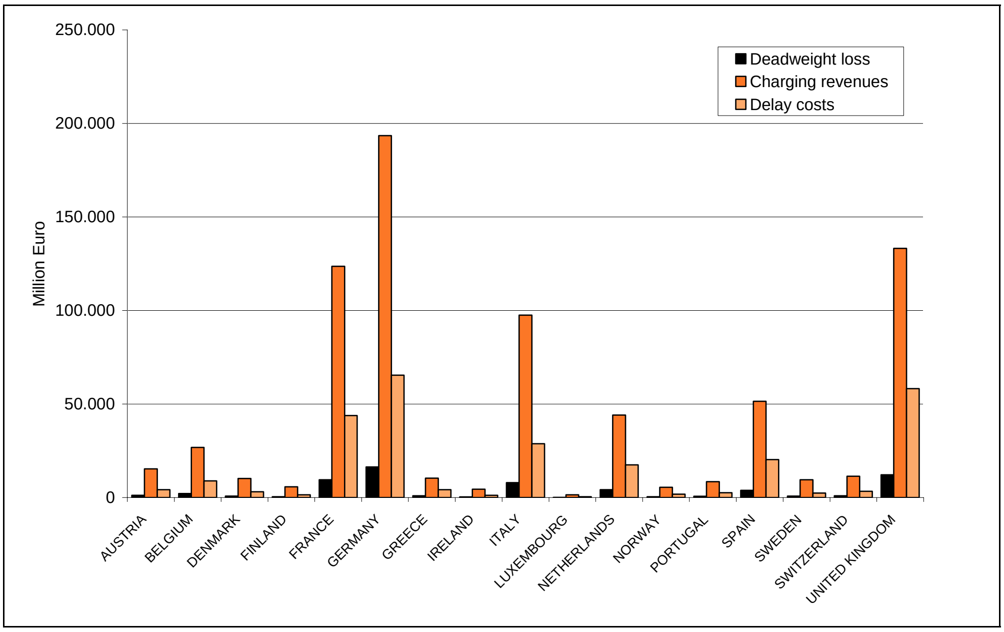


Figure 3-1: Total economic congestion costs, expected charge revenues and delay costs per country 2000 according to Maibach et al. 2004

Figure 3-2 is derived from the results of Maibach at al. (2004) by presenting the average delay costs in road transport allocated to cars and to HGVs in the 17 countries investigated. This indicator is not appropriate to express the congestion situation within a particular region, but it helps to compare the conditions between countries. The results clearly indicate that the Netherlands and the UK suffer most from road congestion, followed by France, Germany and the remaining Benelux countries.

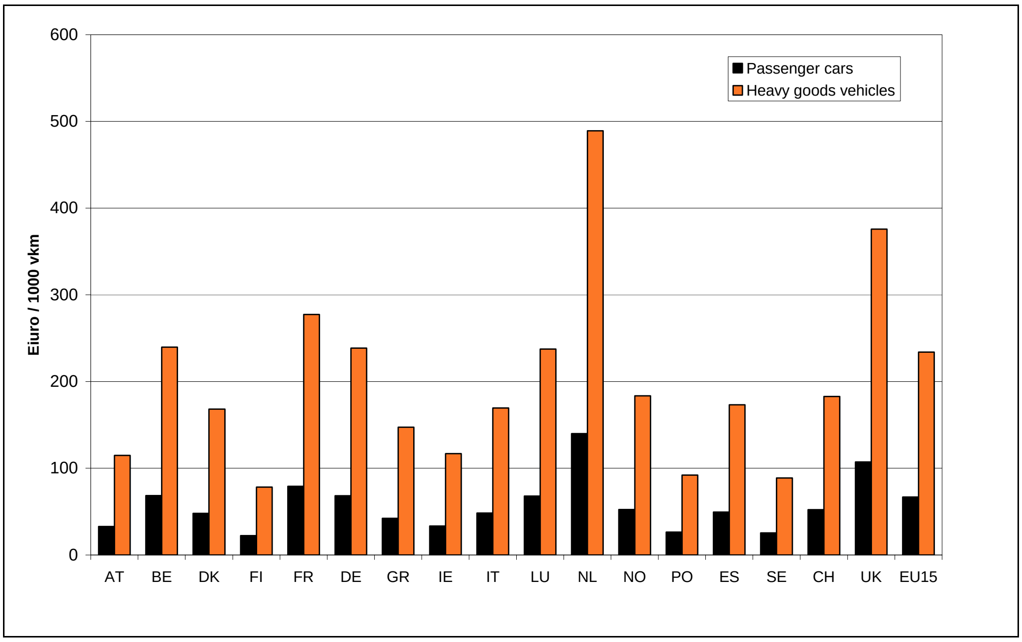


Figure 3-2: Average delay costs in road transport per country for cars and HGVs 2000 according to Maibach et al. 2004

The higher costs per HGV-km compared to passenger car kilometres has three reasons: First, the valuation of delays per passenger car unit (PCU) is roughly 50% higher than for cars and second, HGVs in average consist of two to three PCU. Moreover, HGV traffic concentrates on the congested motorways while car traffic is more spread across the network.

When looking at the country comparison, the authors of the study limit the significance of the findings because the density and quality of the digitised road networks used for calculating congestion costs greatly influence the level of results. Although the GISCO-Networks used in the 2004 study are based on GIS information the quality of countries covered might differ. On the other hand, this Europe-wide modelling approach appears to have clear advantages over the attempt to compare national studies.

Of the 18 countries covered by the UNITE study, congestion costs were only reported for half of the countries. The remaining results contain inter-urban as well as urban road transport and public passenger services. The latter mostly consists of bus travel and thus is part of road transport. This scope is also met by Maibach et al. 2004. The delay costs due to road congestion found by the two studies are compared in Table 3-5, where for Maibach et al. (2004) the additional cost as well as the Deadweight Loss Approach are presented (compare Figure 3-1).

Table 3-5: Comparison of annual delay costs 2000 between Maibach et al. (2004) and UNITE (million Euros)

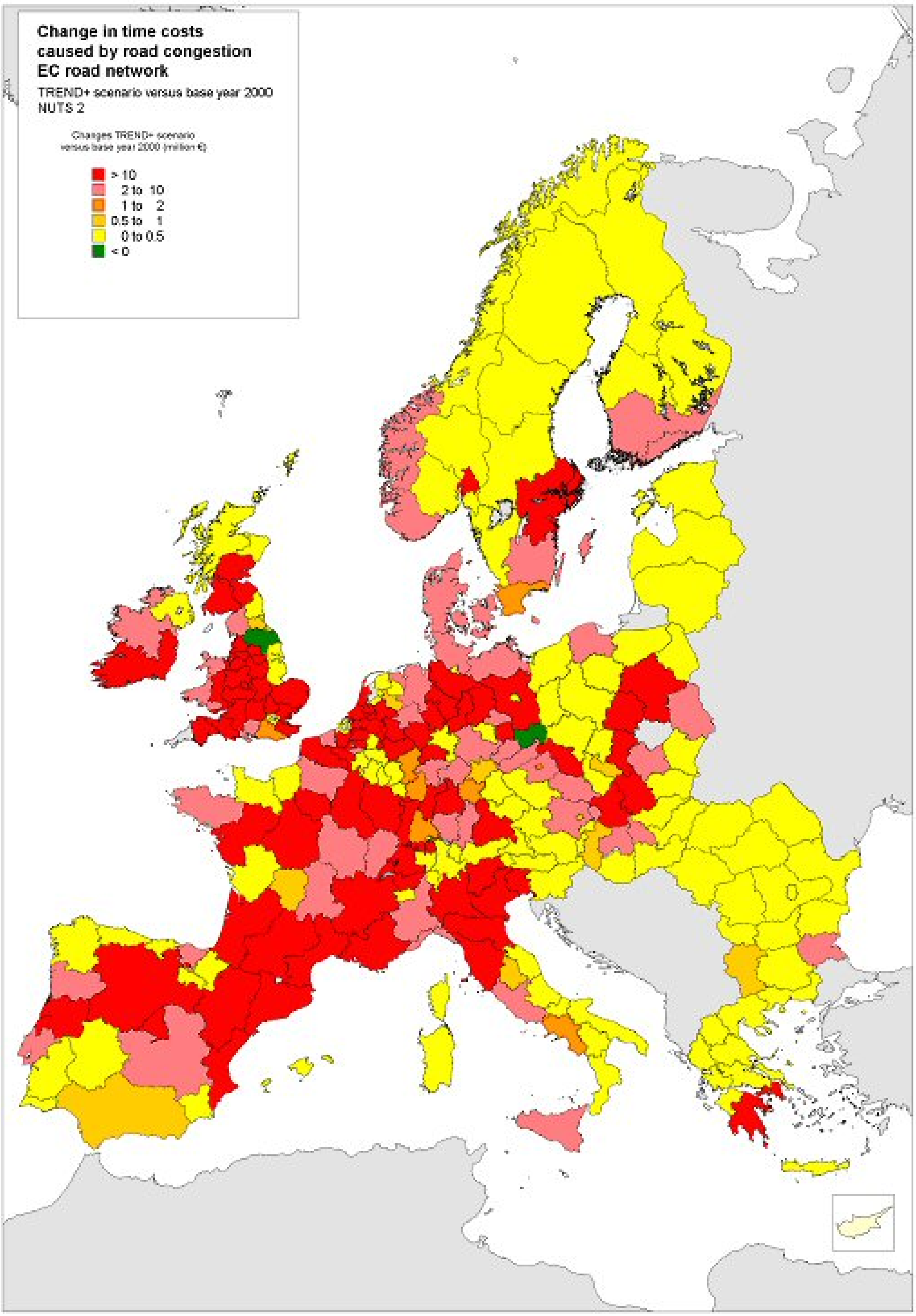
Country	**UNITE**, Link et al. 2001, 2002a, 2002b	**External Costs of Transport,** Maibach et al. 2004	
	ACA	**ACA**	**DWL**
Austria	1,589	4,250	1,224
Belgium	:	8,901	2,186
Denmark	407	3,037	814
Estonia	:	Not covered	Not covered
Finland	:	1,472	462
France	:	43,873	9,500
Germany	17,506	65,383	16',54
Greece	5,239	4,199	931
Hungary	792	Not covered	Not covered
Ireland	:	1,228	337
Italy	:	28,752	8,019
Luxemburg	:	399	110
Netherlands	3,103	17,534	4,263
Norway	Not covered	1,862	468
Portugal	141	2,592	666
Spain	3,726	20,325	3,880
Sweden	:	2,372	761
Switzerland	651	3,349	936
UK	19,371	58,241	12,108

The ACA results computed by UNITE for most countries appear much lower than those of Maibach et al. (2004), although the same basic method has been applied. The difference of the two studies lies in the network and demand data bases for the single countries, which are not consistent, and the reference travel speed considered. The high degree of sensitivity of the congestion computation to the two factors have been identified and discussed by the two studies.

On the other hand, the ACA approach followed by UNITE shows results very similar to the deadweight loss computed by Maibach et al. (2004). As the two studies use the same value of travel time savings (VOT), the resulting difference between UNITE and the ACA results of Maibach et al. (2004) is explained by the cautious definition of the reference travel speed in the UNITE country accounts.

3.1.3 The TEN-STAC project

The TEN-STAC project (NEA et al. 2004) computed differences in congestion levels for a huge number of investment scenarios mainly in the Trans-European rail network. Figure 3-3 shows the changes in travel time costs on the road between the reference scenario 2000 and the year 2020 in case all currently existing investment plans are realised. The comparison of the 2000 base case and the 2020 trend scenario shows that in most regions of western and central Europe congestion-driven time costs increase by 10% and more, while the periphery regions rather remain unaffected.



Source: NEA et al. 2004

Figure 3-3: Development of annual total delay costs 2000 to 2020 with the implementation of current policy plans in Europe

The numerical values underlying Figure 3-3, aggregated by countries, were obtained from the TEN-STAC consortium and will be evaluated in the course of the study.

The study defines congestion by the difference of actual and free flow travel times. Actual travel times where determined by distributing annual traffic volumes to groups of hours of equal traffic loads. The respective traffic flows where then assigned to an attributed digitised

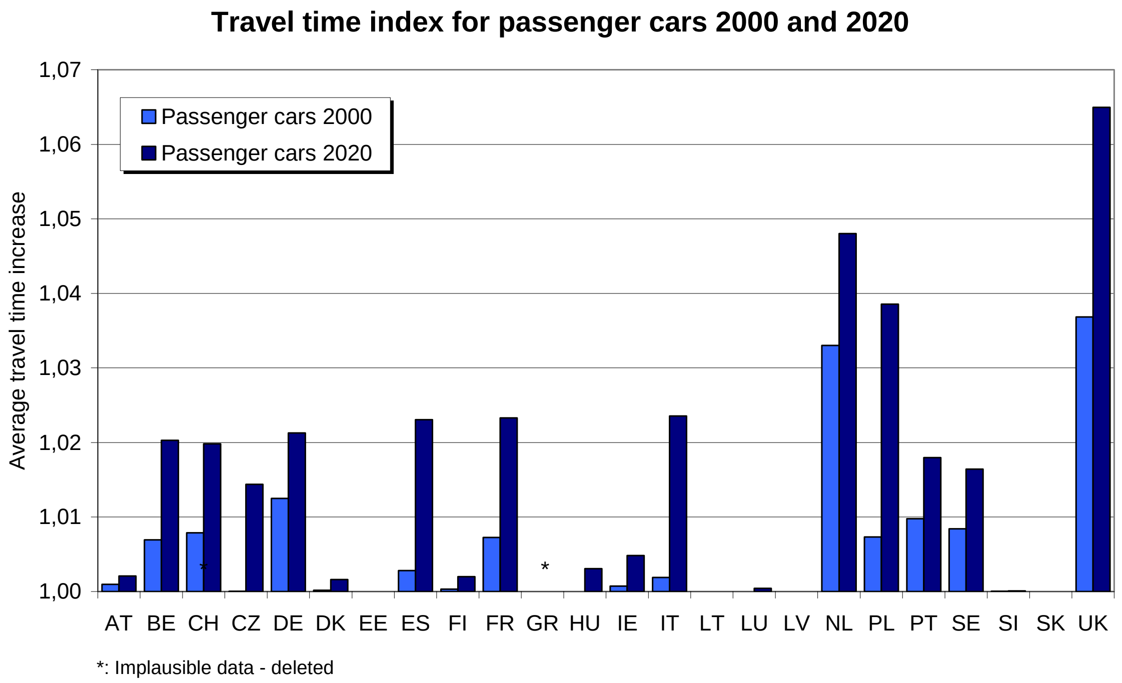
European road network by the traffic model VACLAV (NEA et al. 2004). Free flow speeds have been set to the designe speed by road class as defined in the EWS road assessment manual for Germany (FGSV 1997). Given that most countries besides Germany post speed limits on the inter-urban road network, the respective time losses are over-estimated for most countries.

The focus of the study is on assessing the difference in user-related and external transport costs between various investment scenarios. Thus, the absolute level of congestion is of secondary order for the purpose of the study. To isolate the direct effects of the TEN investment scenarios the study has restricted the assessment of road congestion to parts of the TEN network. As the available data sets from the UNITE study do not contain the share of passenger and freight vehicle movements corresponding to this partial analysis the derivation of average cost figures and the allocation of congestion costs to vehicle classes appears problematic.

Nevertheless, the relative completeness of the country converage of the TEN-STAC project, including all 25 EU Member States plus Switzerland and a number of eastern European countries, makes it attractive to take a closer look at the results. After a top-down separation of the results between passenger and freight vehicles a travel time index, expressing the relative increase of journey times due to congestion was computed. Free flow speeds of 130 kph for cars and 80 kph for lorries where chosen. the results are presented by Figure 3-4 for cars and by Figure 3-5 for lorries showing the results for the base year 2000 and the trend scenario 2020.

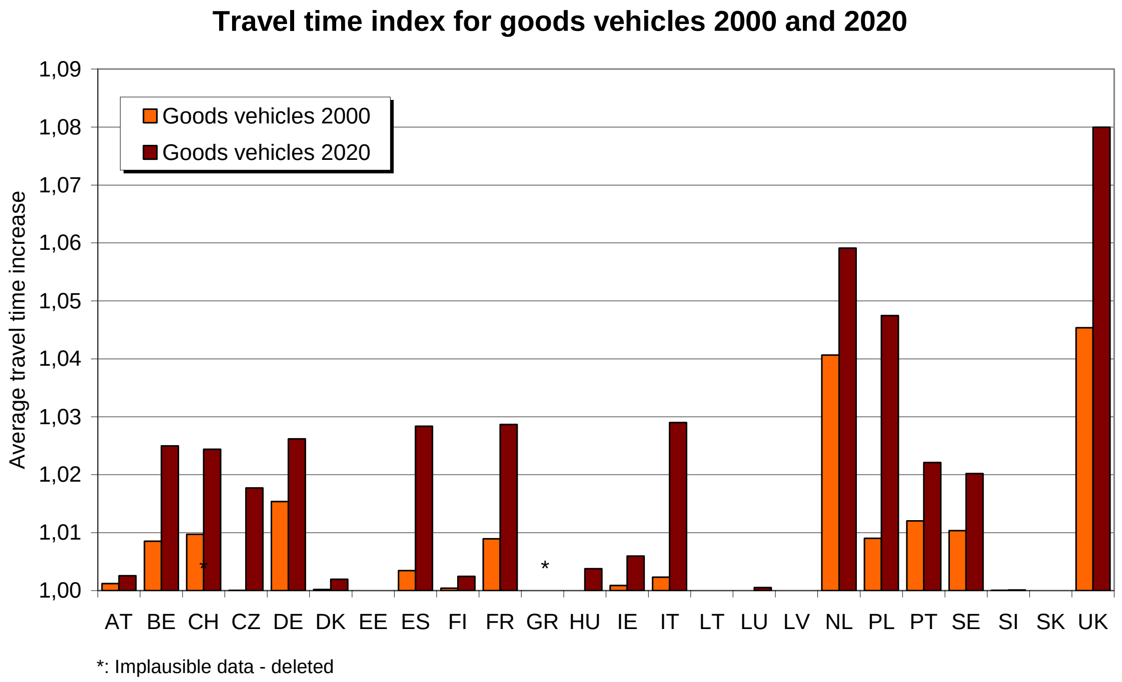
The results indicate that:

- The impact of road congestion appears rather uneven between the countries. The results for Greece and Slovakia have been eliminated due to extraordinarily high results; and the Netherlands, Poland and the UK appear far above the average.
- More important: Nearly all countries face a drastic increase in congestion levels until 2020. This assumption is based on a scenario where current national investment plans are carried on, but the EC does not implement the TEN-T investment projects.



Source: NEA et al. 2004

Figure 3-4: Development of annual total delay costs 2000 to 2020 with the implementation



Source: NEA et al. 2004

Figure 3-5: Development of annual total delay costs 2000 to 2020 with the implementation

3.1.4 The European Road Users' Survey

The Perceived Quality Approach based on interviews with road users followed by the European Road Users' Survey 2004 (CEDR 2004) gives the number of trips considered delayed and the perceived reasons for the delays in international road transport. The results found for the 12 countries covered by the study are presented in Figure 3-6. On the European average, 40% of trips are delayed, while national delay rates range from slightly over 20% in Sweden to over 50% in Belgium and Luxemburg. In Belgium, Luxemburg and Germany capacity-driven congestion is considered the major cause of delays, while in all other countries road-works are seen as the most decisive reason for late arrivals.

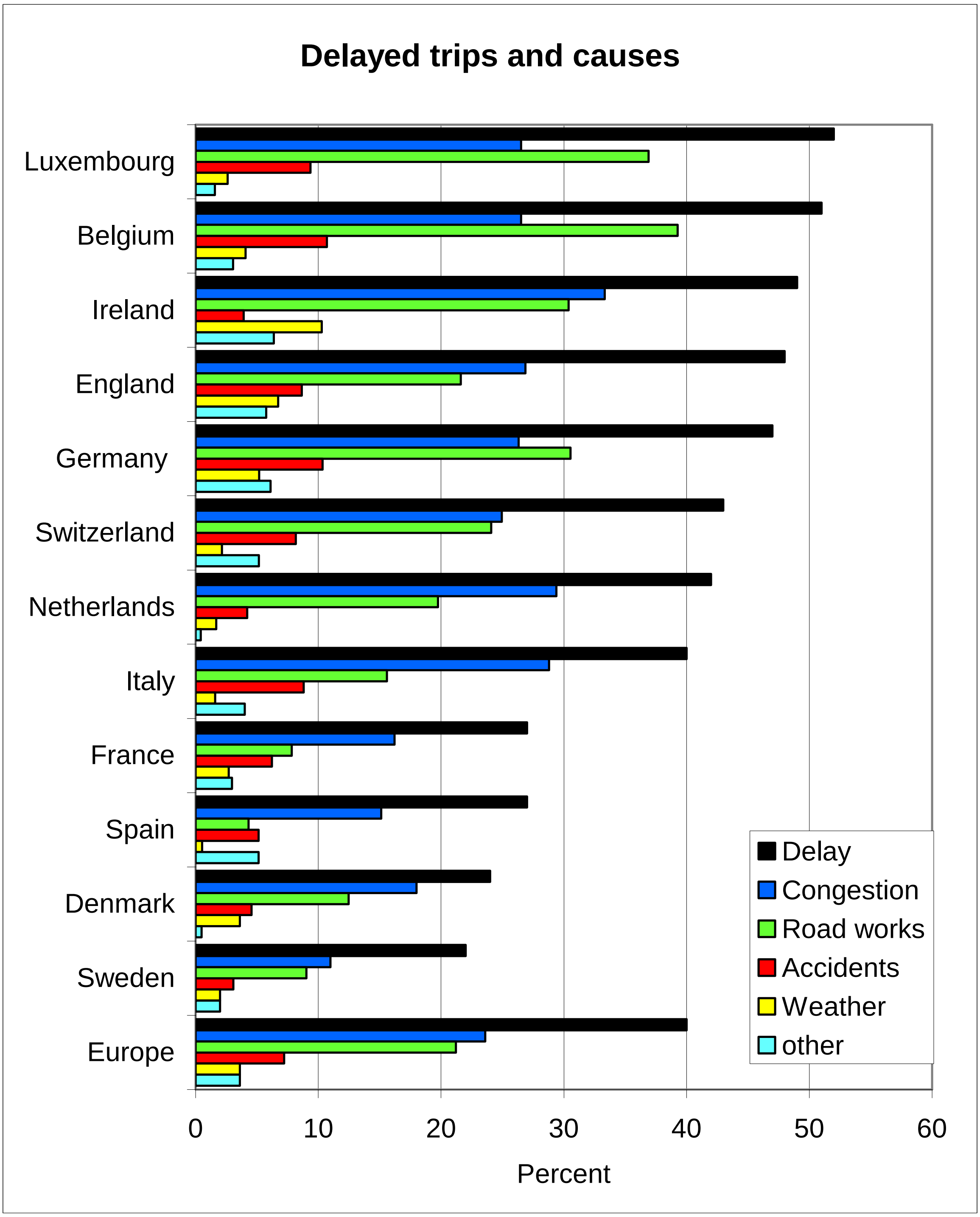


Figure 3-6: Delays and delay causes in international road transport. Data source: CEDR (2004).

The results of the European Road Users' Survey (CEDR 2004) and of the External Costs study (Maibach et al. 2004) do not fully coincide concerning the ranking of countries. But a direct comparison of the two sources is anyway hardly possible, as the European Road Users' Survey does not take into account the severity of delays, which constitutes a major driving factor of congestion costs.

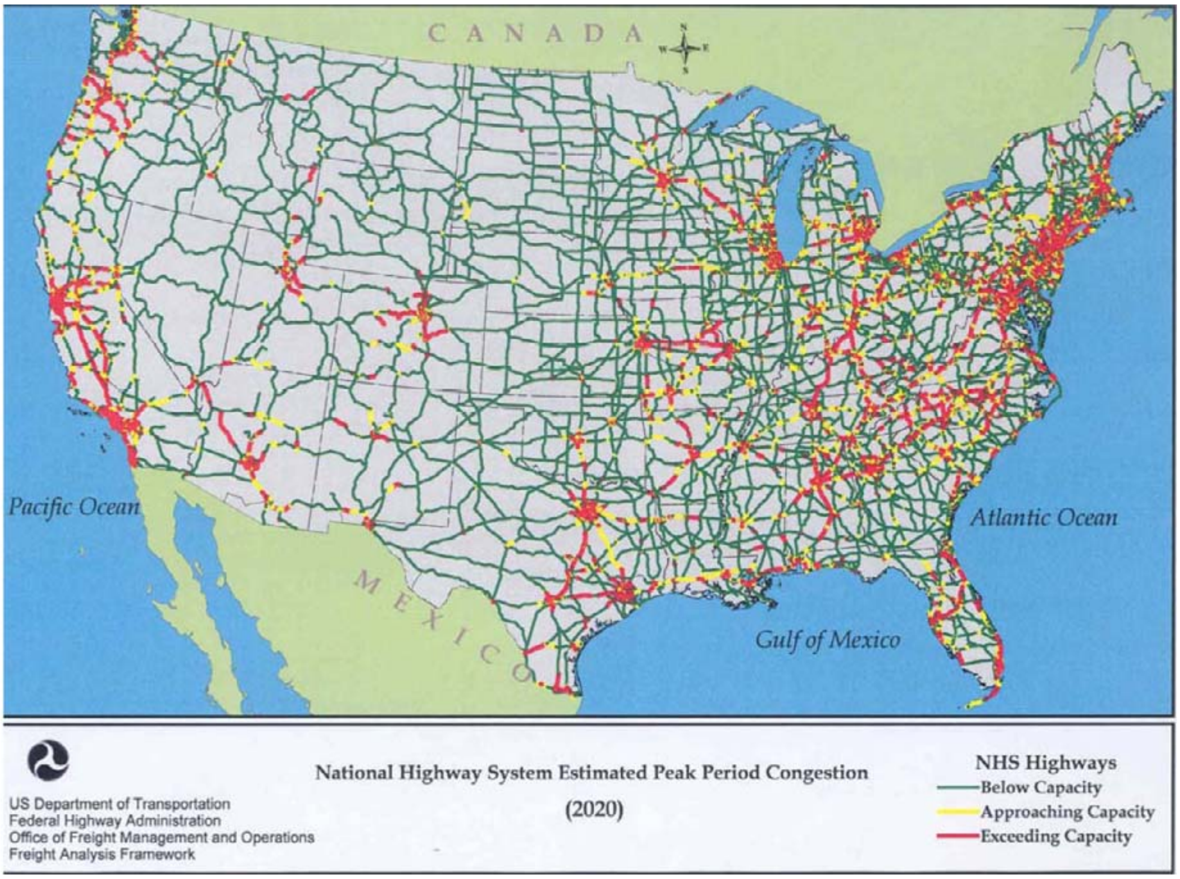
3.1.5 Cambridge Systematics

For goods movement, congestion costs amounts to tens of billions of dollars each year: a conservative estimate of the annual direct cost of recurring truck congestion caused by bottlenecks at highway interchanges and on arterial roads is $7.8 billion (Cambridge Systematics 2005). Table 3-6 presents time losses by location and type of delay and Figure 3-7 provides an overview of the potential evolution of bottlenecks until 2020.

Table 3-6: Truck hours of delay by highway freight bottleneck

Bottleneck Type			National Annual Truck Hours of Delay, 2004 (Estimated)
Constraint	**Roadway**	**Freight Route**	
Interchange	Freeway	Urban Freight Corridor	123,895,000
			Subtotal **123,895,000***
Steep Grade	Arterial	Intercity Freight Corridor	40,647,000
Steep Grade	Freeway	Intercity Freight Corridor	23,260,000
Steep Grade	Arterial	Urban Freight Corridor	1,509,000
Steep Grade	Arterial	Truck Access Route	303,000
			Subtotal **65,718,000†**
Signalized Intersection	Arterial	Urban Freight Corridor	24,977,000
Signalized Intersection	Arterial	Intercity Freight Corridor	11,148,000
Signalized Intersection	Arterial	Truck Access Route	6,521,000
Signalized Intersection	Arterial	Intermodal Connector	468,000
			Subtotal **43,113,000‡**
Lane Drop	Freeway	Intercity Freight Corridor	5,221,000
Lane Drop	Arterial	Intercity Freight Corridor	3,694,000
Lane Drop	Arterial	Urban Freight Corridor	1,665,000
Lane Drop	Arterial	Truck Access Route	41,000
Lane Drop	Arterial	Intermodal Connector	3,000
			Subtotal **10,622,000†**
			Total 243,032,000

Source: Cambridge Systematics 2005



Source: Cambridge Systematics 2005

Figure 3-7: Potential highway bottlenecks 2020

3.1.6 Bottleneck analysis for German motorways

Counting post information and detailed network descriptions have been used by IVV and Brilon (2004) to perform a bottleneck-analysis for the German motorway network including forecasts to 2015 on behalf of the Federal Ministry for Transport, building and Urban Development (BMVBS). According to the Handbook on the Dimensioning of Roads (HBS) congestion was de-fined when the level of service decreases from E (bound traffic) to F (stop and go). This corresponds to a reference travel speed of 75 kph on motorways (compare Table 3-7).

Table 3-7: Level-of-Service grades according to the HBS-Manual

LOS	Description	Average passenger car travel speed
A	Free flow: Virtually no mutual interferences, speeds can be chosen freely within permitted limits.	> 130 kph
B	Nearly free flow. The presence of other traffic participants gets obvious but does hardly restrict the users	> 115 kph
C	Stable flow. Manoeuvrability is restricted and determined by the presence and the behaviour of other vehicles	> 100 kph
D	Still stable flow: High traffic volumes, frequent interferences with obvious mutual disturbance	> 85 kph
E	Approaching capacity. Frequent mutual interferences, only little manoeuvrability. Small disturbances can cause the breakdown of traffic flow	> 75 kph
F	Congestion. Demand exceeds capacity.	< 75 kph

Source: Translated from FGSV (2005)

The analysis was made on an hourly basis using location-specific and weather-dependent speed-flow functions, which have been particularly estimated for the study. According to day-time and weather conditions speed-flow functions have been defined for the situations light-dry, light-wet, dark-dry and dark-wet. Except for delays due to changing weather conditions the analyses was restricted to recurring congestion, i. e. speed reductions due to accidents or road-side construction activities were not considered.

The study has generated to measures of congestion:

- Network congestion, indicating the share of the road kilometres suffering from congestion (LOS-F) at more than 30 hours per year
- Total time losses of all traffic related to the reference speed.

The results of the study for 2000 and 2015 can be summarised as follows:

- In 1997 30% of the motorway network are found to be congested. This share increases to 31% in 2000 and is predicted to be 42% in 2015
- Total annual waiting time 1997 ranges around 900 million vehicle-hours
- Most affected are the urban states (Hamburg, Berlin, Bremen) and the states of Hessen, North-Rhine Westphalia and Lower Saxony.

Detailed results for the 16 German federal states are presented in Table 3-8.

Table 3-8: Motorway sections affected by speeds below 75 kph at more than 30 hours per year 2000 and 2015 by federal state

Federal state	**Motorway network 2000**		**Motorway network 2015**	
	Length (km) per direction	Share (%) of congested sections	Length (km) per direction	Share (%) of congested sections
Bremen	96	80	79	96
Hamburg	162	65	144	80
Hessen	1,912	53	2,016	68
Berlin	132	49	145	83
Baden-Wuerttemberg	2,050	48	2,089	67
North Rhine-Westphalia	4,356	45	4,338	52
Lower Saxony	2,694	38	2,823	49
Bavaria	4,482	26	4,867	36
Rheinland-Palatinate	1,678	23	1,695	39
Schleswig-Holstein	962	19	1,019	33
Thuringa	574	19	1,002	14
Saarland	472	8	457	18
Brandenburg	1,532	7	1,538	17
Saxony	884	6	923	17
Saxony-Anhalt	520	4	743	22
Mecklenburg-Vorpommern	524	2	1,101	17
TOTAL	23,030	31	25,078	42

Source: BMVBW 2004

3.1.7 The English measure of road congestion

Congestion in the UK is evaluated separately for England, Scotland, Wales and Northern Ireland. The Department for Transport carries out congestion surveys on the inter-urban trunk road network (DfT 2001, 2003 and 2005) and in major agglomerations above 250,000 inhabitants (DETR 2000, Crownhurst (2003), Wagner and Kehil 2005 in England where urban and inter-urban surveys are carried out in alternate years (. London surveys are the responsibility of Transport for London (TFL) and are carried out on a three-year cycle. In the inter-urban case measurements concentrate on the most busy trunk road sections. In the urban case all roads with an average daily traffic volume above a threshold of 10,000 vehicles per day plus a selection of less busy links with local importance are monitored. Thus the presented indicators diverge from the "true all roads" figure, but are well suitable to track the development of road congestion over time.

The measure of congestion used is the average time lost per vehicle kilometre. This is defined by dividing the total time lost on a particular part of the road network by the total corresponding number of vehicle kilometres. Time loss is determined by the difference of the average speed of vehicles and the free-flow reference speed.

Actual speeds by road segment and by day period are generated from floating car surveys carried out during six selected months (usually April to June and September to November excluding school holidays and other unusual events). The floating car technique involves the car attempting to equalise the number of vehicles overtaking it with the number of vehicles which it overtakes. The study assumption that there is no congestion during night time is kept under review. 21

The congestion data from different links for a specific time period are combined by weighting them according to the volumes of traffic on each link. The weighted average across all time periods is them determined respectively to produce the overall congestion level.

The reference speed is an estimate of the speed achievable on a particular stretch of road in free-flow conditions when there is very little traffic on that road. For the trunk road network, average speeds observed at low flows (without incidents/roadworks) during weekday off-peak periods are used. In urban areas, speeds collected during the night, when traffic is lightest, are used. In most cases these speeds are well below the roads' speed limits.

The results are presented by road class and by region in case of trunk roads and by size of urban areas, where London is subdivided in several districts. Sample results for 2000 are presented by the following tables:

Table 3-9: Congestion on English trunk roads by class (2000)

	Survey coverage road length	**Average peak speed**	**Congestion (seconds lost per vehicle km)**			
	Km	**Kph**	**Weekday am peak**	**Weekday off-peak**	**Weekday pm peak**	**All periods**
Motorways	2797	87.5	8.8	2.9	6.7	3.8
Dual carriageway A roads	3062	73.3	8.8	3.0	9.0	4.5
Single carriageway A roads	4077	57.3	7.7	4.4	8.1	4.7
All trunk roads	9936	77.0	8.6	3.2	7.6	4.2
Of which, inter-urban target	8522	82.6	-	-	-	3.2

Source: DfT (2000) Transport, Statistics, Roads (2000): A measure of road traffic congestion in england: Method and 2000 Baseline figures. London, 2000

The results are not surprising. The time lost to congestion is shown to be highest during peak weekdays periods.

Disaggregating England into the nine regions shows how congestion varies across the country.

Table 3-10: Congestion on trunk roads in England by regions (2000)

	Survey coverage road length	**Average peak speed**	**Congestion (seconds lost per vehicle km)**			
	Km	Kph	Weekday am peak	Weekday off-peak	Weekday pm peak	All periods
East	1381	78.4	8.4	2.4	7.3	3.8
East Midlands	1382	81.3	3.8	1.8	4.5	2.1
London	256	40.4	37.8	16.2	28.0	18.9
North East	478	79.8	5.5	0.7	7.6	2.7
North West	1405	78.0	9.3	5.1	8.2	5.0
South East	1506	79.9	9.7	2.8	7.4	4.2
South West	1292	88.7	1.6	0.5	3.7	1.1
West Midlands	1184	76.4	8.9	3.3	8.5	4.4
Yorkshire and the Humber	1052	82.4	5.8	2.2	5.0	2.7
All trunk roads	9936	77.0	8.6	3.2	7.6	4.2

Source: A Measure of Road Traffic Congestion in England: Method and 2000 Baseline figures

Table 3-11: Congestion in London and in large urban areas (2000)

	Survey coverage road length	Average peak speed	Congestion (seconds lost per vehicle-km)		
	km	kph	Weekday peak	Weekday off-peak	All periods
Greater London	2151	25.0	65.8	45.5	35.7
Central London	*174*	*15.5*	*120.0*	*134.3*	*69.3*
Inner London	*462*	*18.0*	*109.8*	*68.1*	*53.7*
Outer London	*1516*	*29.5*	*50.1*	*30.3*	*27.1*
Conurbations	2314	35.2	34.4	16.8	17.2
Other large urban areas	1161	33.6	36.9	18.4	21.0
All urban areas (Including London)	5626	30.4	46.4	27.6	24.8

Source: DfT (2000) Transport, Statistics, Roads (2000): A measure of road traffic congestion in england: Method and 2000 Baseline figures. London, 2000

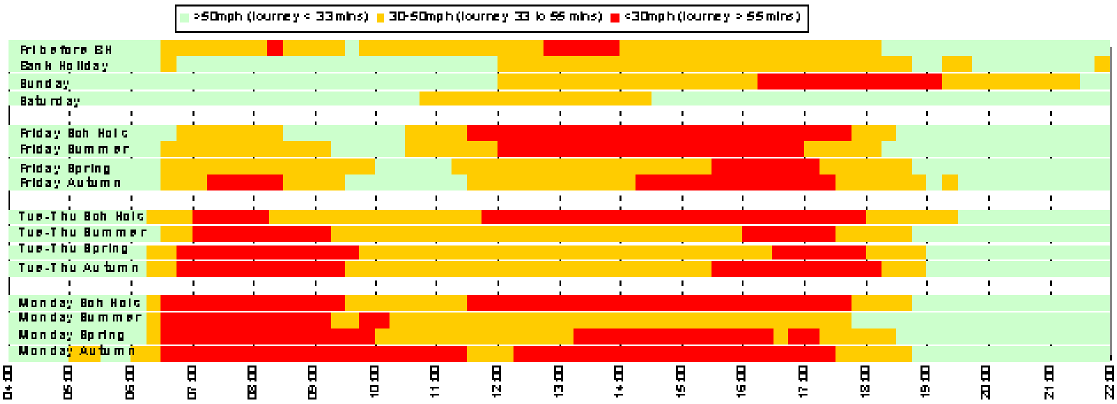
Table 3-11 shows time series of congestion, measured in time losses against free flow speed, in English urban areas other than London from 1993 to 2004. The table shows that the degree of development of congestion figures is independent of the severity of congestion. However, it is to be noted that the methodology of speed recording between 1996 and 1999/00 has slightly changed and thus the development of the congestion indicator is to be considered carefully.

Table 3-12: Congestion in English large urban areas excluding London 1993 to 2004

Area	Average peak hour travel speeds (kph)					
	1993	1996	1999/00	2002	2004	Change 1993-2004
Teeside	50.6	46.4	49.4	55.0	49.6	-1.0
Brighton/Hove	37.1	41.0	42.7	42.6	47.0	9.9
Portsmouth			43.7	42.6	46.4	2.72
Tyneside	34.9	39.8	44.2	44.6	40.5	5.6
Plymouth	40.3	38.6	34.7	36.8	35.0	-5.3
West Midlands	35.5	32.3	33.9	33.4	33.0	-2.6
Leeds/Bradford	34.1	31.2	33.4	32.6	32.8	-1.3
Merseyside	34.2	33.8	30.7	34.6	31.8	-2.4
Hull	33.0	31.2	30.6	29.9	31.8	-1.1
Southampton	29.6	29.8	25.1	26.7	31.2	1.6
Bournemouth/Poole	37.3	32.3	32.0	33.6	31.0	-6.2
Blackpool			30.9	29.8	30.7	-0.16
Stoke/Newcastle-under-Lyme	30.1	33.1	36.8	38.6	30.1	0.0
Sheffield	27.4	27.7	27.4	30.4	29.9	2.6
Greater Manchester	33.1	34.1	29.9	31.4	29.0	-4.2
Bristol	30.9	29.6	29.8	28.0	28.5	-2.4
Nottingham	29.9	28.8	29.3	25.9	26.6	-3.4
Leicester	25.3	28.2	27.2	25.0	23.5	-1.8
All large urban areas	**33.6**	**33.9**	**33.0**	**33.3**	**32.5**	**-1.12**

Source: Wangeci C and Kehil M (2005): Traffic Speeds in English Urban Areas: 2004. Department for Transport. London, May 2005

The UK motorist's forum suggests supplementing these aggregate measures by more user-friendly indicators of individual links. It is proposed to use the „journey Time Variability", which is the 90% slowest trip (90-percentile travel time) minus the free-flow travel time. An example for the Brimingham Region is given below:



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Source: http://www.cfit.gov.uk/mf/reports/imcfinal/index.htm

Figure 3-8: Proposed presentation of local congestion indicators for the UK

3.1.8 Scottish Executive congestion study 2003

In 2005 the Scottish Executive has carried out the first volume of a planned regular series of congestion monitoring studies entitled "Congestion on Scottish Trunk Roads 2003" (http://www.scotland.gov.uk/Publications/2005/03/20810/54225). Data is delivered by roughly 500 monitoring sites in 10 areas. Actual travel speed is related to the undisturbed free flow speed determined on all network sections. In addition a floating car data survey by 4 to 6 vehicles per day with a total of 344 vehicle-days was carried out in order to calibrate total network results. Aggregations of local measurements over the entire study network provide the basis for the first set of indicators:

- Additional Travel Time per Annum: Total of actual additional travel time against free flow travel times. Result 2003: 7.1 billion hours.
- Average Time Lost per Vehicle Kilometre: This computes as total time losses divided by total vehicle kilometres and thus relates it to the users' perspective and allows benchmarking between regions. Result 2003: 4.95 seconds/vkm.
- Cost of Trunk Road Congestion per Annum: Total additional travel time is multiplied by value of time figures developed by DfT (10£/h) which provides a figure which measures the cost to the economy per annum caused by congestion on the trunk road network. Fuel and operating costs are not considered. The national results for 2003 are presented by Table 3-13

Table 3-13: National results 2003 for scottish trunk roads

Parameter	Unit	2003 value
Additional travel time per annum	Hours	7,104,000
Average time lost per vehicle kilometre	seconds	4.95
Cost of trunk road congestion per annum	UKP	71,040,000

In addition a series of Local Trunk Road Congestion Indicators on 44 distinct routes between 10 local areas are presented: Total time losses, average time losses per vehicle kilometre and total costs of time losses are computed as in the national case but related to single network segments. Moreover, the following additional indicators are computed:

- Journey Time Reliability: This is the share of journeys taking less than 115% of the average journey time.
- Total Time Lost per Km per Day. The indicator relates total time losses per day to the route length and thus provides a measure to compare total costs of different routes.
- Three Congestion Bands. This methodology separates the congestion experienced into three bands of Mild, Serious and Severe. This indicates the impact of congestion by the vehicles affected, the duration in hours and the time lost per route-km. If related to vehicle-km rather than to vehicles the first indicator and also total time lost per congestion band could well be applied to greater areas. The definition of the congestion bands and the 2003 results are as follows:

Table 3-14: Traffic levels by LOS cluster in Scotland

Congestion type	Speed drop	Vehicles affected		Congestion duration		Time lost per km (hrs)
		Number	%	Hours	% of day	
Mild	>10%<25%	26359	76.21%	16.25	67.71%	9.7
Serious	>25%<50%	1679	4.85%	0.5	2.08%	10.5
Severe	>50%	3799	10.96%	1.5	6.25%	76.3

- Annual Average Daily Congestion Index: ratio of the Free Flow Speed to the actual speed averaged over the whole day. This is used as a general indicator of congestion allowing comparisons over time but not between routes.

3.1.9 The PACA congestion study

To prepare the public debate on the LGV (Ligne à Grande Vitesse: high speed line) in PACA (Provence – Alpes – Côtes d'Azur), RFF (Réseau Ferré de France) aimed at receiving a panorama on traffic conditions and road network congestion in the region of PACA, and more particularly on the roads, that permit the same access as the LGV. The study (7), realised by the CETE Méditerranée, first gives a diagnosis of the present situation. Then it gives some predictions for the 2020 horizon.

The synthesis gives the following results:

- Roads accessing to agglomerations are congested in different proportions: from 54 days of important discomfort on the A8 in Aix-en-Provence to more than 340 days in St Laurent du Var.
- More than 70% of the days are superior to the discomfort threshold and more than 45 % of the days present at least one hour of high congestion: on the A8 at the entrance of Nice (in St Laurent du Var), at the north of Nice, on the A50 at the entrance of Marseille and on the A51 at the entrance of Aix-en-Provence (Luynes).

- At the entrance of Toulon and between Aix-en-Provence and Marseille (Cabriès), there are between 40% and 60% of the days superior to the dis-comfort threshold. On these sections, days with more than one hour of con-gestion are not so important (between 4% and 7%).
- Significant disturbed conditions are also observed near Lançon (A7), Antibes and at the east of Aix-en-Provence (A8). On these sections, there are between 15 and 30% of the days superior to the discomfort threshold.
- The other sections of the motorway network still benefit from a relative fluidity, with-out major congestions.
- The volumes of traffic are important on the main road RN98: more than 95% of the days present one hour of congestion. The main roads accessing to Aix-en-Provence are also congested: 77% of the days present at least one hour of congestion on the RN96 in Mayrargues and 63% on the RN7 in St Cannat.

In short, the Mediterranean Corridor, in spite of a very powerful and highly developed infra-structure network, does not escape from a very alarming traffic situation. Figure 3-9 summa-rises the most important current traffic conditions: the total of all "zones" of saturation and of the "zones" of significant accident risks, represents nearly 40 % of total na-tional roads and motorways.

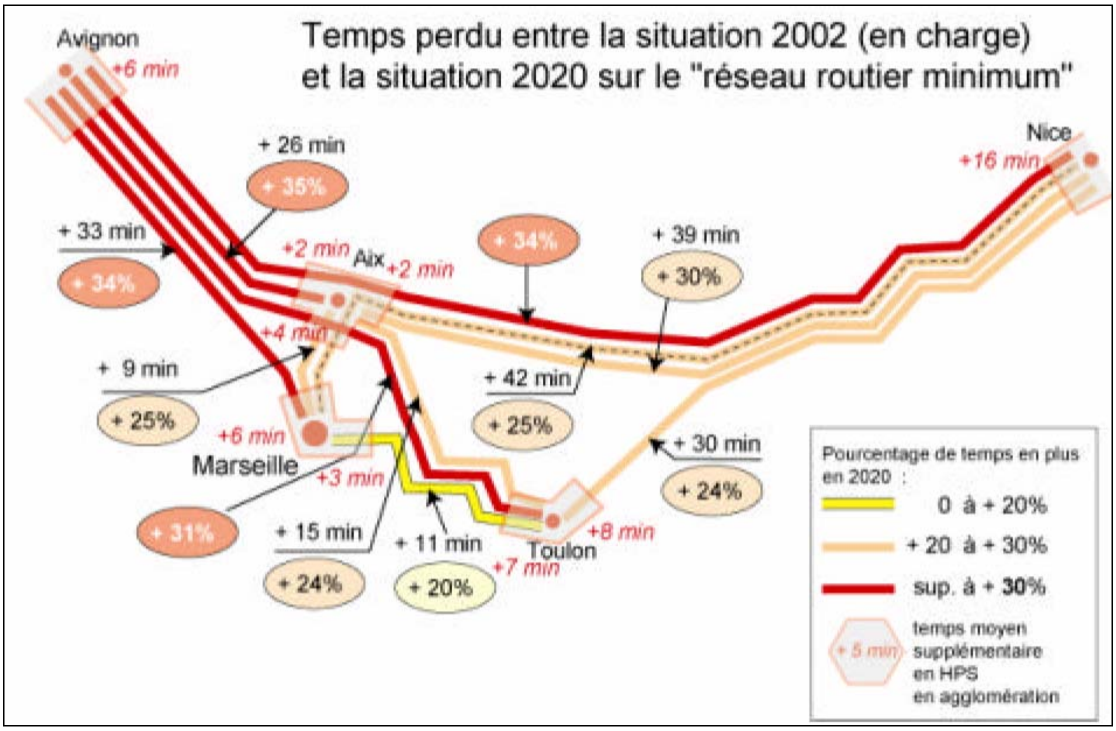
Source: CETE Méditerranée (2004))

Figure 3-9: Development of travel times in the PACA region 2002 to 2020

These traffic conditions highly disturb the travel times between the main cities, and more particularly at the end of the travel that means downtown: the average travel speed in peak period in the centre of Toulon is about 15 kph, around Marseille it is about 36 kph (and only 16 kph in the centre).

The analysis of the PACA congestion proposes a prediction for 2020 horizon based on the following assumptions : GDP average growth of 2.3% per year, coal duty, de-crease by 10 % of the railway price (for passengers), low decrease of the air passen-ger transport…The results of this prediction indicate that the situation will getting worse and very quickly. The impact of road development is low compared to the in-crease of road traffic. Travel times increase dramatically on all the studied sections (7);

Figure 3-10 gives an estimate of the average wastes of time, between the situation 2002 and the situation 2020 under the assumption of a constant network. The worsening of travel times is very sensitive to the principal agglomerations within the PACA region, driven by the urban peak hour conditions.



Source: CETE Méditerranée (2004)

Figure 3-10: Development of travel times in the PACA region 2002 to 2020

The analysis of the evolution perspectives in the valley of the Rhône and in the corridor of the Languedoc indicates that the traffic conditions will get worse on the A7 and the A9 within the coming 20 years. These predictions are based on the following assumptions: a GDP average growth between 1.9% and 2.3%, a barrel price between 60 $ and 100 $ and different infrastructures developments (32).

3.1.10 The Dutch Filemonitor

These are the annual road traffic congestion reports that AVV publishes each year. These make use of the data of the network of automatic congestion detection faclities on the Dutch road network. This report is used to identify mobility trends and to see where mobility increases most.

Congestion is measured as the stand-still of vehicles (queues) lasting for a certain time and extending to a certain length. Out of these data the report also gives a list of the 10 worst locations in terms of congestion, as shown in Table 3-15 and Figure 3-11. Table 3-15 shows ranking, trend (up/down), ranking in previous year, road, description, direction, traffic jam density and changes relative to the last year. Traffic jam density is expressed in km*min. Figure 3-11 presents the locations of the top 10 congestion spots graphically.

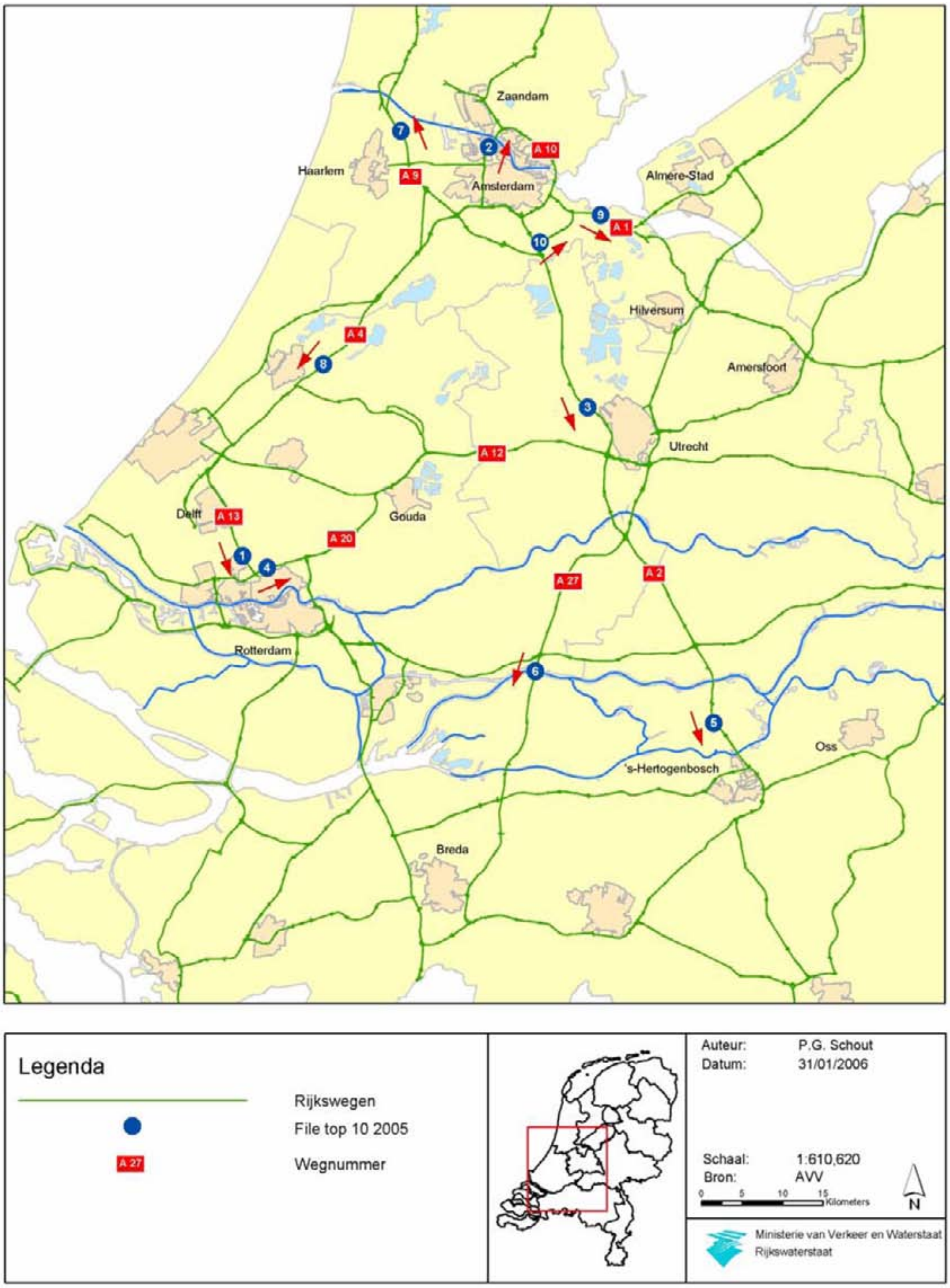
Table 3-15: Top 10 congestion spopts on Dutch inter-urban roads 2005

Plaats 2005		Plaats 2004	Weg	Omschrijving	File richting	Filezwaarte (duizend km*min)	Verandering t.o.v. 2004 (%)
1	↑	2	A13	Delft-Zuid - Rotterdam	Rotterdam	291	12
2	↑	3	A10 Ring West	Westpoort - Coentunnel	Coentunnel	179	6
3	↑	11	A2	Maarssen - Utrecht	Utrecht	136	43
4	↑	7	A20	Rotterdam-Centrum - Crooswijk	Gouda	124	12
5	↑	55	A2	Zaltbommel - Hedel	's Hertogenbosch	122	155
6	↓	5	A27	Knp Gorinchem-Merwedebrug	Breda	121	6
7	↑	13	A9	Knp Rottepolderplein – Velsen	Alkmaar	121	30
8	↓	4	A4	Roelofsarendsveen - Hoogmade	Den Haag	118	-28
9	↓	6	A1	Diemen - Muiden	Amersfoort	111	-1
10	↓	9	A9	Holendrecht – Diemen	Diemen	110	8

Source: AVV (2004)

The columns (from left to right) translate as follows:

(1) Rank 2005;
(2) Rank 2004;
(3) Road;
(4) Description;
(5) Direction;
(6) traffic jam severity (1000 km * min.);
(7) Change against 2004 (%)



Source: Filemonitor 2005

Figure 3-11: Map of top 10 congestion spots 2005

It also analyses the trends, break down the traffic jams into causes (accidents/engineering works/structural lack of capacity) as shown in Table 3-16.

Table 3-16: Congestion causes on Dutch trunk roads 2004/05

Cause	Congestion severity 2005	Congestion severity 2004	Change against 2004
Restricted capacity	8.55	8.78	0.23 (+3%)
Accidents	1.31	1.28	-0.05 (-4%)
Road works	0,52	0,46	-0,06 (-12%)
Total	**10,38**	**10,50**	**0,12 (+ 1%)**

Source: Filemonitor 2005

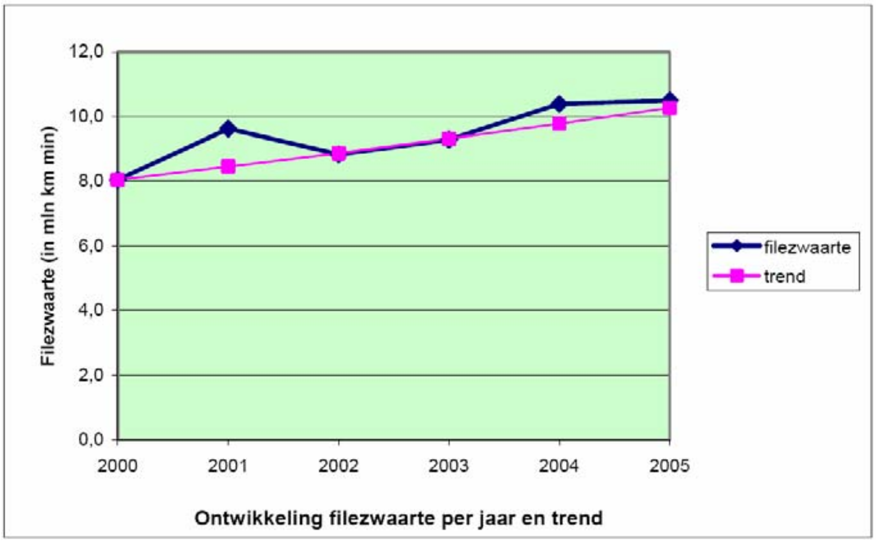
It uses the following definitions:

- Traffic jam: A traffic situation on a main road (motorway or dual carriageway) is called a traffic jam if the speed slows down to less than 50 km/h over a length of more than 2km.
- Traffic jam length: The length of the traffic jam is tracked from the first reporting of it until the reporting of its end. Based on these reports the average traffic jam length is calculated, called traffic jam length in short, expressed in kilometres.
- Traffic jam duration: The duration of the traffic jam, expressed in minutes, is the time passing between the start of the traffic jam being reported and the end being reported.
- Traffic jam intensity: To allow for comparisons of traffic jams of varying length and duration, the term traffic jam intensity was introduced. This the product of the above-mentioned length and duration. Traffic jam intensity is expressed in km*minutes. The total traffic intensity is the sum of the intensities of the traffic jams that occurred in the measuring time-window on that location
- Traffic performance: Total of the realised displacement by all vehicles on the main road network, expressed in vehicle*km.

Methodewijziging fileregistratie (change in method of traffic jam registration)

In relation to the above-mention traffic jam reports, a document was published explaining the new way of measuring traffic jams. This new method resulted from the taking into use of a new automated system of counting traffic jams, which is considerably more accurate than the old system, which still involved registering traffic jams manually. As more traffic jams are now observable than before, this makes it difficult to compare old and new statistics. The biggest difference is that now, many more short-lasting traffic jams are observed than before.

Three different correction methods were used to fit the old and the new data together, each of these methods was analysed in the paper. Resulting is a trend curve showing a steady increase of the density of congestion in the Netherlands as shown by Figure 3-12



Source: Filemonitor 2005

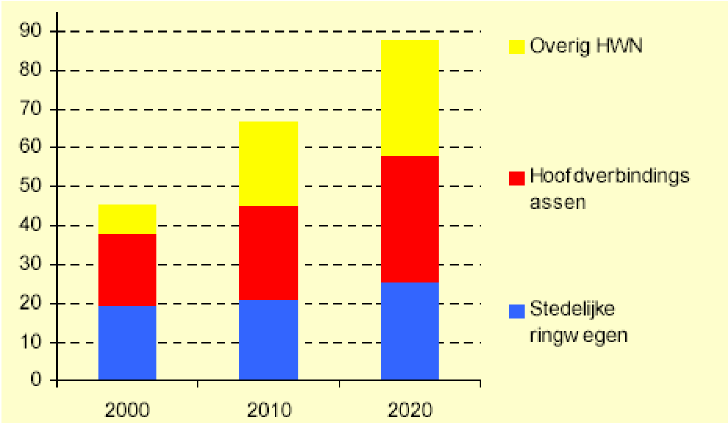
Figure 3-12: Trend of congestion severity in the Netherlands 2000 to 2005

3.1.11 Fileverkenning (Congestion forecast)

The document (Adviesdienst Verkeer en Vervoer (2004)) seeks to give an insight into the future development of traffic jams and other delays on the Dutch motorway network. It considers various aspects of delays in traffic, such as travel time reliability, total travel time loss, the direct costs of the travel time loss, and the fact that some road users will chose alternatives to avoid the travel time loss and its costs (the demand drop or latent demand). The other effects to society, such as economy (attractiveness for companies), safety and environment, are not discussed – the document is meant for policy development.

In order to contribute to national policy development, the document sought to give a total picture of the development in the Netherlands, and a forecast of the delays of various types of road users, for different time horizons.

The diagram below gives an example of the sort of information contained in the report. It shows the yearly total travel loss hours (in mln) for the three types of infrastructure: urban ring roads (motorway and dual carriageway, in blue), main transport axes (motorways, red) and other main infrastructure (blue).

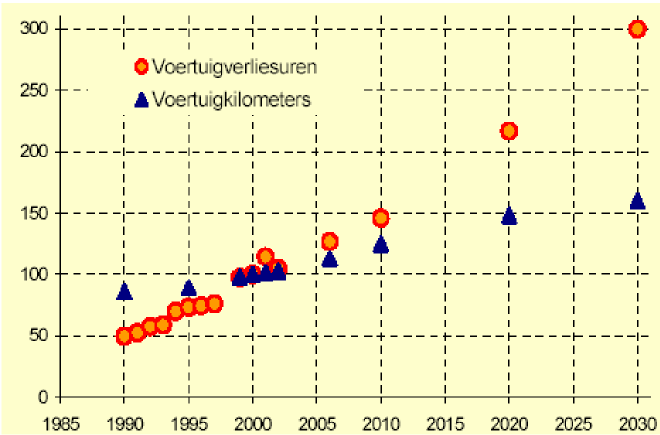


Source: http://www.minvnw.nl/cend/oei/Images/1-1105979533_tcm67-54215.pdf

Figure 3-13: Congestion forecasts by network type

It contains the information used in the Mobility Paper (same figures) but is more detailed. Many of the forecasts were made using the earlier-mentioned RAND model and LMS model.

As another example, it also predicts total vehicle-km and vehicle loss hours until 2030, as shown in the following graph:



Source: http://www.minvnw.nl/cend/oei/Images/1-1105979533_tcm67-54215.pdf

3.2 Urban road studies

3.2.1 The US Urban Mobility Report

The Urban Mobility Report is carried out annually on behalf of the US Department of Transport, Federal Highway Administration (FHWA) for a sample of 85 urban areas. These are grouped into 13 very large, 26 large, 30 medium sized and 16 small areas. For each sample city the study determines a number of mobility-related indicators by modelling recurring and incident-related delays.

Congestion estimates are restricted to pre-defined peak periods lasting from 6:00 – 9:30 am and from 3:30 to 7:00 pm. This period is assumed to carry 50% of daily traffic. The real prevailing condition in off-peak are not considered by the study indicators. The reference speeds for delay estimates are 60 mph (96 kph) on freeways and 35 mph (56 kph) on major streets.

Recurring delays are computed from vehicle traffic per lane and traffic speed equations for peak hours using network inventory and traffic density data mainly from FHWA's Highway Performance Monitoring System (HPMS) and from the states. Real speed measurements are not used as most cities do not provide such data in sufficient quality. However, the database of speed records is currently improved in many agglomerations by the Federal Highway Administration's Mobiity Monitoring Programme (TTI/CS 2004).

Incident-related delays are computed from recurrent congestion by incident-delay-ratios for freeways and for principal arterial streets. The incident-delay-ratios for freeways are determined site-specific by detailed incident statistics. The ratios range from 0.6 for San Diego to 2.5 for Pittsburgh and others. For principal arterial streets the incident delay ratio is set to a country-wide constant of 1.1 as here local differences are not that striking.

The Indicators computed are:

- Total annual travel delay (hours) = the daily number of vehicle-hours of delay times 1.25 persons per vehicles times 250 working days.
- Annual delay per traveller (hours) = Total annual travel delay divided by the number of inhabitants.
- Travel time index (TTI) = the weighted average of the ratio between travel rates (h/km) in peak and in free-flow conditions relating to all delay purposes.
- Excess fuel consumption (gallons): Average fuel economy in congestion (gallons/km) = 8.8 – 0.25 * Average peak period congested system speed (mph). Total fuel wasted = total daily travel delay, average peak period system speed times average fuel economy.
- Congestion costs (US$) consists of the three components passenger vehicle delay costs, passenger vehicle fuel costs and commercial vehicle operating costs.
- Delay (hours) and congestion costs (US$) saved by operational treatments
- Delay (hours) and congestion costs (US$) saved by public transportation

For all indicators rankings among the 85 areas are given. Annual delays per traveller and the travel time index are tracked from 1982 to 2003. Table 3-17 shows the results of the two main indicators "Annual delay per traveller" and "Travel time index" for 2003 across all 85 areas.

Table 3-17: Key mobility measures in US cities 2003

Urban Area	Annual Delay per Traveler		Travel Time Index	
	2003 Value	Rank	2003 Value	Rank
85 Area Average	**47**		**1.37**	
Very Large Average	**61**		**1.48**	
Very large (13 areas)				
Los Angeles-Long Beach-Santa Ana, CA	93	1	1.75	1
San Francisco-Oakland, CA	72	2	1.54	3
Washington, DC-VA-MD	69	3	1.51	4
Atlanta, GA	67	4	1.46	5
Houston, TX	63	5	1.42	6
Dallas-Fort Worth-Arlington, TX	60	6	1.36	19
Chicago, IL-IN	58	7	1.57	2
Detroit, MI	57	8	1.38	12
Miami, FL	51	13	1.42	6
Boston, MA-NH-RI	51	13	1.34	21
New York-Newark, NY-NJ-CT	49	18	1.39	10
Phoenix, AZ	49	18	1.35	20
Philadelphia, PA-NJ-DE-MD	38	27	1.32	25
85 Area Average	**47**		**1.37**	
Large Average	37		1.28	
Large (26 areas)				
Riverside-San Bernardino, CA	55	9	1.37	14
Orlando, FL	55	9	1.30	28
San Jose, CA	53	11	1.37	14
San Diego, CA	52	12	1.41	8
Denver-Aurora, CO	51	13	1.40	9
Baltimore, MD	50	17	1.37	14
Seattle, WA	46	20	1.38	12
Tampa-St. Petersburg, FL	46	20	1.33	23
Minneapolis-St. Paul, MN	43	22	1.34	21
Sacramento, CA	40	25	1.37	14
Portland, OR-WA	39	26	1.37	14
Indianapolis, IN	38	27	1.24	32
St. Louis, MO-IL	35	31	1.22	35
San Antonio, TX	33	33	1.22	35
Providence, RI-MA	33	33	1.19	42
Las Vegas, NV	30	39	1.39	10
Cincinnati, OH-KY-IN	30	39	1.22	35
Columbus, OH	29	42	1.19	42
Virginia Beach, VA	26	46	1.21	39
Milwaukee, WI	23	48	1.21	39
New Orleans, LA	18	54	1.19	42
Kansas City, MO-KS	17	57	1.11	60
Pittsburgh, PA	14	63	1.10	64
Buffalo, NY	13	65	1.10	64
Oklahoma City, OK	12	68	1.10	64
Cleveland, OH	10	73	1.09	69

Source: Schrank and Lomax (2003)

Table 3-18: Key mobility measures in US cities 2003 (continued)

Urban Area	Annual Delay per Traveler		Travel Time Index	
	2003 Value	Rank	2003 Value	Rank
85 Area Average	**47**		**1.37**	
Medium Average	**25**		**1.18**	
Medium (30 areas)				
Austin, TX	51	13	1.33	23
Charlotte, NC-SC	43	22	1.31	26
Louisville, KY-IN	42	24	1.24	32
Nashville-Davidson, TN	37	29	1.18	48
Tucson, AZ	36	30	1.31	26
Jacksonville, FL	34	32	1.18	48
Oxnard-Ventura, CA	33	33	1.23	34
Memphis TN-MS-AR	33	33	1.22	35
Bridgeport-Stamford, CT-NY	32	37	1.29	29
Salt Lake City, UT	31	38	1.28	30
Albuquerque, NM	30	39	1.17	52
Raleigh-Durham, NC	27	43	1.19	42
Birmingham AL	27	43	1.17	52
Omaha NE-IA	23	48	1.18	48
Honolulu, HI	20	50	1.19	42
New Haven, CT	20	50	1.13	58
Sarasota-Bradenton, FL	19	52	1.25	31
Grand Rapids, MI	19	52	1.14	55
El Paso, TX-NM	18	54	1.17	52
Allentown-Bethlehem, PA-NJ	17	57	1.14	55
Richmond, VA	17	57	1.09	69
Hartford, CT	16	60	1.11	60
Fresno, CA	13	65	1.14	55
Albany-Schenectady, NY	13	65	1.08	72
Toledo, OH-MI	12	68	1.10	64
Tulsa, OK	12	68	1.10	64
Akron, OH	12	68	1.09	69
Dayton, OH	11	72	1.08	72
Rochester, NY	7	80	1.07	77
Springfield, MA-CT	7	80	1.06	80
85 Area Average	**47**		**1.37**	
Small Average (16 areas)	**13**		**1.11**	
Small (16 areas)				
Colorado Springs, CO	27	43	1.19	42
Charleston-North Charleston, SC	25	47	1.20	41
Pensacola, FL-AL	18	54	1.12	59
Cape Coral, FL	15	61	1.18	48
Salem, OR	15	61	1.11	60
Beaumont, TX	14	63	1.07	77
Spokane, WA	10	73	1.08	72
Little Rock, AR	10	73	1.06	80
Eugene, OR	9	76	1.11	60
Boulder, CO	9	76	1.08	72
Columbia, SC	9	76	1.06	80
Laredo, TX	8	79	1.08	72
Bakersfield, CA	7	80	1.07	77
Corpus Christi, TX	7	80	1.05	84
Anchorage, AK	5	84	1.05	84
Brownsville, TX	4	85	1.06	80

Source: Schrank and Lomax (2003)

Table 3-19 shows the development of a wide range of urban congestion indicators for the whole country.

Table 3-19: Time-serices of US urban congestion indicators

Measures of…	1982	1993	2002	2003
… Individual Traveler Congestion				
Annual delay per peak traveler (hours)	16	40	47	47
Travel Time Index	1.12	1.28	1.37	1.37
Number of urban areas with more than 20 hours of delay per peak traveler	5	37	50	51
… The Nation's Congestion Problem				
Total hours of delay (billion)	0.7	2.4	3.6	3.7
Total gallons of "wasted" fuel (billion)	0.4	1.3	2.2	2.3
Cost of congestion (billions of 2003 $)	$12.5	$39.4	$61.5	$63.1
… Travel Needs Served				
Daily vehicle-miles of travel on major roads (billion)	1.06	1.66	2.09	2.14
Annual person-miles of public transportation travel (billion)	22.9	35.1	43.7	43.4
… Expansion Needed to Keep Today's Congestion Level				
Additional lane-miles of freeways and major streets	7,638	6,459	4,927	5,002
Additional daily public transportation riders (million)	8.6	8.2	7.2	7.3
… The Effect of Some Solutions				
Hours of delay saved by				
Operational treatments (million)	NA	NA	301	336
Public transportation (million)	269	696	1,097	1,096
Congestion costs saved by				
Operational treatments (billions of 2003 $)	NA	NA	$5.0	$5.6
Public transportation (billions of 2003 $)	$4.6	9.0	$18.2	$18.2

NA – No Estimate Available
Pre-2000 data do not include effect of operational strategies and public transportation.
Travel Time Index – The ratio of travel time in the peak period to travel time at free-flow conditions. A Travel Time Index of 1.35 indicates a 20-minute free-flow trip takes 27 minutes in the peak.
Delay per Peak Traveler – The extra time spent traveling at congested speeds rather than free-flow speeds divided by the number of persons making a trip during the peak period.
Wasted Fuel – Extra fuel consumed during congested travel.
Expansion Needed – Either lane-miles or daily riders to keep pace with travel growth (maintain congestion).

Source: Schrank and Lomax (2005)

The Study summarises its results as follows: Congestion continues to grow in America's urban areas. Despite a slow growth in jobs and travel in 2003, congestion caused 3.7 billion hours of travel delay and 2.3 billion gallons of wasted fuel, an increase of 79 million hours and 69 million gallons from 2002 to a total cost of more than $63 billion. The solutions to this problem will require commitment by the public and by national, state and local officials to increase investment levels and identify projects, programs and policies that can achieve mobility goals. The 2005 Report shows that the current pace of transportation improvement, however, is not sufficient to keep pace with even a slow growth in travel demands in most major urban areas.

The long-term trend from 1982 to date is described as follows:

- Mobility problems have increased at a relatively consistent rate during the two decades studied. Congestion is present on more of the transportation systems, affecting more of the trips and a greater portion of the average week in urban areas of all sizes.
- Congestion affects more of the roads, trips and time of day. The worst congestion levels increased from 12% to 40% of peak period travel. And free-flowing travel is less than half of the amount in 1982 (Exhibit 1).
- Congestion has grown in areas of every size. Measures in all of the population size categories show more severe congestion that lasts a longer period of time and affects more of the transportation network in 2003 than in 1982. The average annual delay

for every person using motorized travel in the peak periods in the 85 urban areas studied climbed from 16 hours in 1982 to 47 hours in 2003 (Exhibit 2).

- The delay statistics in Exhibit 2 point to the importance of action. Major projects, programs and funding efforts take 10 to 15 years to develop. In that time, congestion endured by travelers and businesses grow to those of the next largest population group. So in ten years, medium-sized regions will have the traffic problems that large areas have now, if trends do not change.

The trend described is illustrated by Figure 3-14.

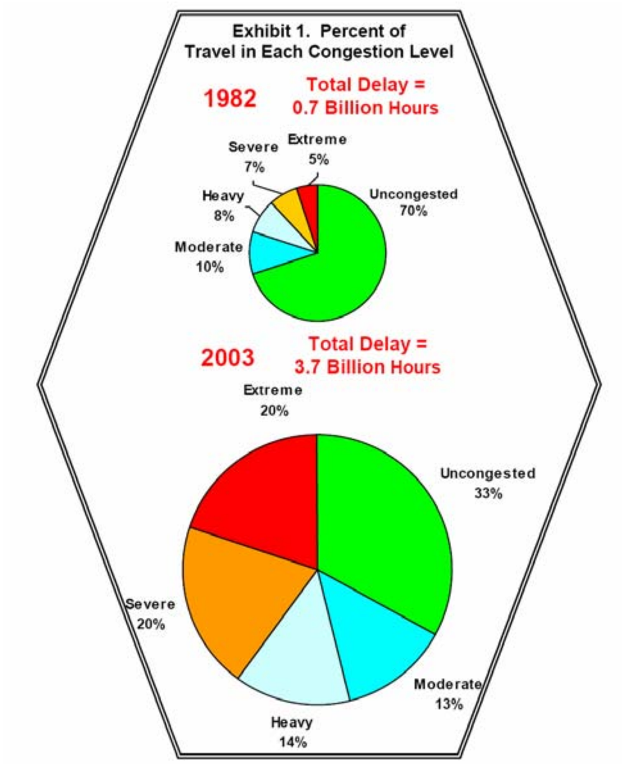


Figure 3-14: Percent of travel by congestion level in US cities 1982 and 2003

3.2.2 The Canadian congestion study

In 2006 Transport Canada has issued a pilot study on congestion costs in nine of its largest urban areas (Transport Canada 2006). The basic methodology follows the approach of the US Urban Mobility Report in that it computes time losses on urban networks using archived traffic flow data. However, there appear several methodological differences:

- The Transport Canada study uses a reference travel speed of 60% of free flow speed in order to set a sound policy target level. Speeds above this threshold will not result in congestion measures even if they drop below free flow speeds.
- The basic output of the Canadian study are total congestion costs per city, including time costs, fuel wasted and greenhouse gas emissions. Average costs or travel time indices as in the US case are not computed.

The subsequent tables present the most relevant results:

Table 3-20: Total costs of congestion in Canadian cities (CA$)

Urban Area	Year	at 50% Threshold	at 60% Threshold	at 70% Threshold
Vancouver	2003	$402.8	$516.8	$628.7
Edmonton	2000	$49.4	$62.1	$74.1
Calgary	2001	$94.6	$112.4	$121.4
Winnipeg	1992	$48.4	$77.2	$104.0
Hamilton (all)	2001	$6.6	$11.3	$16.9
Toronto	2001	$889.6	$1,267.3	$1,631.7
Ottawa-Gatineau (all)	1995	$39.6	$61.5	$88.6
Montréal	1998	$701.9	$854.0	$986.9
Québec City	2001	$37.5	$52.3	$68.4
Total, all urban areas		$2,270.2	$3,015.0	$3,720.6

Source: Transport Canada (2006)

Table 3-21 shows that in average time based delay costs amount to roughly 90% of congestion costs, which corresponds to European and US experiences. The remaining costs are due to wasted fuel (204500 CA$) and greenhouse gas emissions (44100 CA$)

Table 3-21: Share of delay costs at congestion in Canadian cities

Urban Area	Year	at 50% Threshold	at 60% Threshold	at 70% Threshold
Vancouver	2003	92.4%	91.9%	92.7%
Edmonton	2000	--	--	--
Calgary	2001	88.1%	88.0%	90.2%
Winnipeg	1992	79.4%	85.4%	90.1%
Hamilton (all)	2001	87.4%	90.4%	92.4%
Toronto	2001	84.4%	87.0%	90.4%
Ottawa-Gatineau (all)	1995	92.3%	93.1%	93.9%
Montréal	1998	87.4%	87.0%	88.5%
Québec City	2001	92.4%	91.9%	92.7%
Total, all urban areas		90.6%	91.8%	93.0%

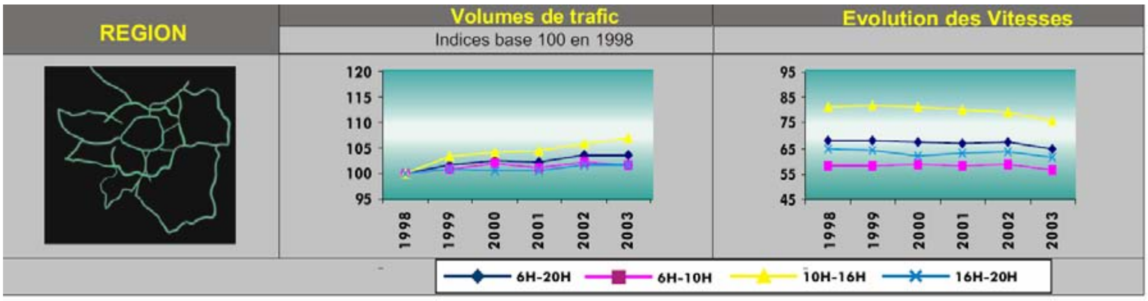
Source: Transport Canada (2006)

3.2.3 The Ile-de-France traffic quality monitor

On the basis of traffic observations the prefecture of the region Ile-de-France publishes annual statistics on travel speeds by time of day and the share of congested road space. The data reported is differentiated by:

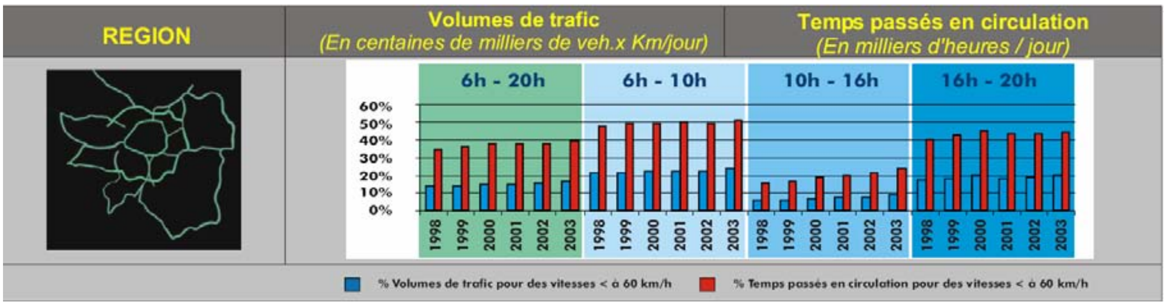
- Time of day (6:00 – 10:00, 10:00 – 16:00, 16:00 – 20:00), by
- Type of networks (two groups of radial roads and two ring roads) and by
- reason (recurring congestion, incidents and blockades / road works)

Some results are presented in Figure 3-15 and Figure 3-17 for the period 1998 to 2003 and by Figure 3-17 and Table 3-22 for recent years.



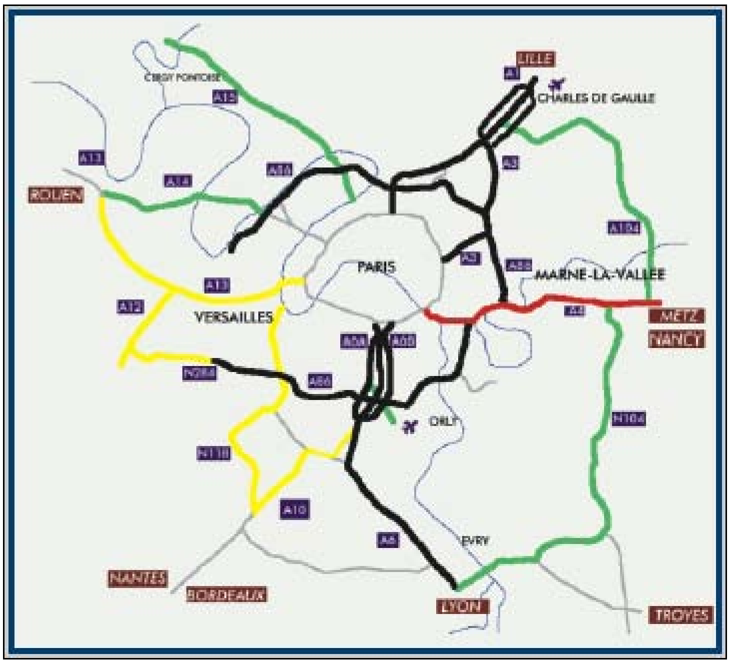
Source: Prefecture de la région d'Ile-de-France (2005)

Figure 3-15: Average speeds in Ile-de-France 1998 to 2003



Source: Prefecture de la région d'Ile-de-France (2005)

Figure 3-16: Vehicle kilometres at a speed < 60 kph in Ile-de-Freance 1998 to 2003



Indicator:Share of traffic jams per link at total traffic jams by share of link length at cumulated link length:
— 0-0.5; — 0.5-1; — 1-1.5; — 1.5-2
Source: Prefecture de la région d'Ile-de-France (2005):

Figure 3-17: Congestion severity by route 2003, Ile-de-France

Table 3-22: Causes of congestion 2002 and 2003, Ile de France

Cause	**2002**	**2003**
Recurrent congestion	85.4 %	83.8 %
Incidents / accidents	10.7 %	13.9 %
Road works	4.0 %	2.3 %

Source: Data from Prefecture de la région d'Ile-de-France (2005)

3.2.4 The Greater Copenhagen Congestion Study

On the national level the urban congestion study of the Copenhagen region (hvid 2004a and 2004b), jointly commissioned by the Copenhagen Municipality, the Greater Copenhagen Authority and the Danish Road Directorate defines congestion as follows: "Congestion expresses the impediments which road users cause each other in terms of reduced manoeuvrability when travelling in the traffic system" The reduced manoeuvrability applies to both the longitudinal and the cross directions and is measured in terms of (reduced) speed and (increased) density. Reduced speed may cause e.g. delays, while increased density may cause reductions in manoeuvrability, service levels, security, etc

Congestion is expressed by four levels (negligible, beginning, high and critical), which are matched with values for travel speed and density. Density is, however, only used for inter-urban roads as the presence of signalling systems make this measure meaningless in urban areas. It is determined by measuring traffic volume and speed and is expressed relative to maximum density (Tmax). On arterial and urban roads, travel speed is calculated as a function of average speed measured at selected points and the measured or estimated delay in signal-controlled intersections. Speeds are expressed relative to the free-flow travel speed (Vfree), which is determined by the travel speed possible when there is no congestion on the road section. Bus speeds are determined excluding wait times at bus stops.

Table 3-23: Definition of congestion levels according to Hvid (2004)

Congestion level	Description	Density	Speed
Negligible congestion	Density is insignificant, travel speed is not significantly reduced – road users experience no significant impediments.	≤ 20% of Tmax	≥ 80% of Vfree
Beginning congestion	Density is an impediment to road users, but travel speed is still not significantly reduced	> 20% of Tmax	≥ 80% of Vfree
High congestion	Density is now high and travel speed is significantly reduced – road users experience impediments in terms of both density and delays.	≥ 23% of Tmax	< 80% of Vfree
Critical congestion	Traffic flow is 'stop-and-go'. Density is very high and travel speed is greatly reduced - the traffic flow is unstable and travel time unpredictable.	≥ 60% of Tmax	≤ 40% of Vfree

Tmax = maximum density, Vfree = free flow speed under non-congested conditions.

The final computation of congestion levels was carried out on the basis of speed-flow and flow-density diagrams as the regular measurement of speed and density particularly on urban roads is rare. The functions have been estimated for a set of sample road segments collecting extensive data on car travel and public transport during one week. Finally, the following indicators have been calculated for Copenhagen municipal roads and for Danish motorways:

- Travel speed index, i.e. travel speed (km/h) relative to free-flow travel speed (km/h). This index provides a more accurate description of the traffic flow on individual sections than the levels of congestion listed above, but is not as easily illustrated for a large road net-work, and does not directly reflect the impediments encountered.
- Total delay, measured on all road sections and vehicles in the system (hours or monetary terms). Delays are measured relative to free-flow and may be divided into the above four levels of congestion.
- Average delay is total delay related to the respective vehicle kilometres.
- Road congestion, i.e. the total length or share of roads affected by critical congestion.
- Vehicle distance congestion, i.e. the total amount or share of kilometres performed by cars under critical congestion.
- Vehicle time congestion, i.e. the total amount or share of travel time of cars at the time performed under critical congestion.

The study reveals and indicates that most of the Copenhagen road network is not significantly affected by congestion. The calculations were made for morning peak hours in 2001 for municipal car and bus travel and for motorway car traffic. In total, delays make up less than 20% of the free-flow travel time. Taking the average delay per vehicle-kilometre as the indicator of the severity of traffic congestion, it can be stated that congestion only plays a significant role within the Copenhagen agglomeration. Table 3-24 presents some comparative results for Copenhagen municipal roads and the motorways in Denmark.

Table 3-24: Congestion levels in the greater Copenhagen region (data source: Hvid 2004)

Region	**Contribution of critical congestion to**:			**Average delays** (sec./pass.-km)	**Total delays** (hours)
	Traffic (vehicle-km)	Network (road-km)	Delays (hours)		
Municipality	5%	2%	32%	50	4000
Motorways	13%	11%	51%	25	3500

4 International trends in road and rail transport

This section takes stock of various sources of information on congestion and delays in the European transport systems from an international as well as from the individual countries' perspective. Research studies, public reports, position papers of stakeholder groups and lobby associations will be considered, as well as qualitative statements from various institutions.

The contents of this section reflect the current state of work in Task 3 of the COMPETE project. Currently, considerable input by European and national institutions is still pending and thus the "panorama of congestion" shaped below does not in any way reflect a final stage for most countries. The presentation of interim results rather aims to explore ways to present the vastly heterogeneous information available for the different countries in a transparent and user-friendly way.

4.1 Inter-urban road transport

In Inter-urban road transport a number of studies quantifying the level of congestion have been conducted. In contrast to the US approach they mainly refer to the economic costs of congestion rather than tracking congestion trends over time. Total congestion costs related to GDP and the derived Travel Time Index are presented in Table 4-1 for the Infras-IWW-study (Maibach et al. 2004), the TEN-STAC project (NEA et al. 2004) and the UNITE project (Nash et al. 2003). The Travel Time Index is the ratio between total time spent in transport and the time required in case free flow speeds was possible for all trips. From these results the following conclusions emerge:

- The congestion results of the TEN-STAC project appear to be roughly 100 times lower than the other studies. This might be caused by the network delimitation or inconsistancies between time losses and the related traffic volume.
- UK results from UNITE are extraordinarily high, which can be explained by the consideration of urban congestion in the UK accounts, while other countries had no information on this issue.
- The Infras/IWW results appear to be the most balanced among the three studies reviewed. They pronounce the presence of inter-urban road congestion along the "blue banana" from the UK via France, Germany to Italy.

Despite the low level of the TEN-STAC results the study provides the most comprehensive basis for comparing inter-urban road congestion across Europe as here all countries (besides Cyprus and Malta) have been included.

In addition, a number of national approaches to quantify trunk road congestion exist, but they are hardly comparable by numbers as the definitions and methodologies diverge too widely. From the available results and from the responses of the member states the following statements on inter-urban road congestion can be made:

- Germany, the Benelux countries and the southern part of the UK take an outstanding position as here the density of large urban areas causes considerable congestion on the entire trunk road network. The introduction of the HGV motorway toll in Germany has not stopped this trend.
- France, Poland, Spain and a number of periphery countries perceive congestion on the trunk road network as a problem around urban areas. The policy measures against this trend are different: While in Poland a huge program for constructing bypass routes was launched, in France congestion is tacked by traffic demand management strategies. These policy approaches, however, need to be considered from the varying conditions in the countries, including the quality of the road network and the situation of public households.
- In a large number of periphery countries, including Scandinavia, the Baltic countries, Slovakia, Slovenia and Greece inter-urban congestion is not a real issue.
- The Alpine countries Switzerland and Austria mainly suffer from transit traffic from and to Italy. Due to its rigid policy against road transport the Switzerland is concerned by holiday car traffic at some days of the year, while in particular the Brenner route in Austria also suffers from heavy lorry traffic.

Table 4-1: Measures of inter-urban road congestion in Europe

Country	**Congestion costs by GDP**			**Travel Time Index**					
	Infras/ IWW 2000	TEN-STAC 2000	UNITE 1998	TEN-STAC Base 2000		TEN-STAC Trend 2020		Infras/IWW 2000	
	Total	Total	Total	Pass.	Freight	Pass.	Freight	Pass.	Freight
Austria	0.9%	0.002%	0.8%	1.00	1.00	1.00	1.02	1.14	1.08
Belgium	1.4%	0.017%		1.02	1.03	1.02	1.18	1.23	1.12
Czech Rep.		0.000%		1.00	1.00	1.00	1.04		
Denmark	0.8%	0.000%	0.3%	1.00	1.00	1.00	1.01	1.23	1.10
Estonia		0.000%		1.00	1.00	1.00	1.00		
Finland	0.6%	0.001%		1.00	1.00	1.00	1.01	1.11	1.04
France	1.0%	0.017%	1.3%	1.02	1.03	1.01	1.14	1.29	1.12
Germany	1.3%	0.025%	0.9%	1.03	1.04	1.02	1.10	1.27	1.14
Greece	1.2%	0.000%	4.8%	1.00	1.00	1.00	1.00	1.17	1.07
Hungary		0.000%	1.9%	1.00	1.00	1.00	1.01		
Ireland	0.5%	0.003%	0.5%	1.01	1.01	1.00	1.05	1.13	1.06
Italy	1.1%	0.005%		1.00	1.01	1.00	1.13	1.19	1.09
Latvia		0.000%		1.00	1.00	1.00	1.00		
Lithuania	0.9%	0.000%		1.00	1.00	1.00	1.00		
Luxemburg		0.000%		1.00	1.00	1.00	1.01	1.35	1.16
Netherlands	1.6%	0.031%	0.9%	1.05	1.06	1.04	1.15	1.49	1.32
Poland		0.012%		1.01	1.01	1.00	1.08		
Portugal	0.8%	0.121%	0.1%	1.02	1.02	1.01	1.07	1.09	1.04
Slovakia		0.000%		1.00	1.00	1.00	1.50		
Slovenia		0.000%		1.00	1.00	1.00	1.00		
Spain	0.9%	0.006%	0.7%	1.01	1.01	1.00	1.08	1.16	1.06
Sweden	0.5%	0.013%		1.02	1.02	1.01	1.06	1.12	1.05
Switzerland	0.6%	0.000%	0.3%	1.00	1.00	1.00	1.00	1.21	1.09
Un. Kingdom	1.3%	0.060%	1.6%	1.08	1.10	1.06	1.27	1.41	1.19

In the US inter-urban congestion is assessed by the White Paper on freight transport bottlenecks (Cambridge Economics 2005). The study identifies major bottlenecks, in particular where important ports are located within urban centres and at freeway intersections. The report estimates total costs of roughly 9 billion Euros ($7.8 billion) compared to 1.6 billion Euros estimated for the EU15 and Switzerland (Table 4-1).

The evaluation of the country reports has lead to the following picture:

Table 4-2: Expectation of congestion levels by country studies

Country	Situation 2000	Forecast 2020
United States	Serious congestion on interstate highway crossings and where congestion is caused by metropolitan areas	Safetyy-Lu investment programme.
Germany	Highly congested: Ruhr area and around big agglomerations (Berlin, Hamburg, Munich)	investmentds, time variation of HGV toll Traffic shift to rail and waterways
France	Many motorways are currently on the way of saturation. They support the main part of the international transit traffic.	Road Pricing, modal shift and inter-modal capacity …
United Kingdom	Congestion percieved a major issue by DOT. No detailed information on current stat available	10 year plan: Target to reduce road congestion; no concrete reduction limit
Italy	No information - only 1995 data for parts of the network available	n. a..
Spain		
Poland	Congestion problem at agglomerations; roads of generally very bad quality	Construction of bypass routes around cities
Netherlands		
Greece	Only specific parts, exit and construction points	
Portugal	Main problems at radio routes around Lisbon and Porto, Access to major ports	National Road Plan: Minimum LOS B on main roads and LOS C on secodary roads by installation of IST for Information and traffic management plus capacity increase
Belgium	According to numerical values minor problem; Ring-roads Brussels and Anvers	
Czech Republic	Insufficient quality of Infrastructure	
Hungary	Budapest ring and in-going (M3), Budapest-Ballaton on holidays	
Sweden	No problem	
Austria		
Switzerland	Only at city borders and in holiday periods	
Denmark	Only slight congestion around Copenhagen	
Slovakia	Through traffic through district towns	Construction of bypasses
Finland	No problem	
Ireland		
Lithuania		
Latvia		
Slovenia		
Estonia		
Cyprus		
Luxembourg		
Malta		

4.2 Urban congestion

There is no unique way in Europe to assess urban congestion. The most advanced approach is followed by the UK department for Transport and Transport for London by regularly measuring vehicle speeds. For English town, Paris and Copenhagen the available information was sufficient to estimate a travel time index similar to that computed by the Texas Transportation Institute for the US. However, as the data sources are quite different the comparability of the results presented in Table 4-3 is limited.

Table 4-3: Key mobility measures in US cities 2003

Area	Travel time index		
	1993	2004	1993-2004
Paris, Ile-de-France		1,34	
Greater Copenhagen area		1.40	
Greater London		1.84	
Average of other English cities	1.24	1.32	0.08
US 85 Area Average	1.28	1.37	0.09
US Very large average (13 areas)	1.38	1.48	0.10
US Large average (26 areas)	1.19	1.28	0.09
US Medium average (30 areas)	1.11	1.18	0.07
US Small average (16 areas)	1.06	1.10	0.04

Table 4-3 reveals that the development of the travel time index indicating the severity of congestion in English cities is in line with the development of urban congestion in the US.. The same holds for the absolute values except for London, which seems to suffer extraordinarily under congestion.

The following Table 4-4 presents rather old figures for the year 1993, but they provide an insight into the affected network and the users' perception of congestion conditions. The figures reveal that within Europe the UK and the Netherlands suffer most from congestion, while the road quality is perceived very good in Scandinavia and in the US.

Table 4-4: International comparison of congestion figures 1993

	Road network (km/1000 inh.) 1993	Motorways (km/million inh.) 1993	Congestion (% of links) 1993*	Perceived road quality 1995**
USA***	14,5	331	--	9
Japan	6,2	37 (1987)	--	6,2
United Kingdom	6,2	56	24,1	5,9
Germany	7,6	136	7,9	8,3
France	15,8	129	4,5	8,5
the Netherlands	6,1	141	14,8	5,9
Belgium	12,9	169	5,9	8,3
Denmark	13,7	127	0	9,1

Source: ECMT 1998

According to the reports collected from the Member States the situation looks rather heterogeneous in European cities:

- Remarkably, congestion is not considered a major problem for most US citizens as the ability to relocate to non-congested areas within a city or across states is high. The TTI mobility index shows that congestion rises more dynamically in large and medium sized areas than in very large agglomerations.
- The greater London area is a commonly very congested area. However, the introduction of the London Congestion Charge in 2003 has considerably improved the situation. Vehicle speeds have been rising by 5% and both, the frequency and the punctuality of public transport has considerably improved.
- Apart from that, a number of capitals are fully congested, including Paris, Prague and Rome. In some cases Peak traffic has spread out to the off-peak periods, such that off-peak is only visible during night time.
- In most cities, however, congestion is considered rather modest or non existing. However it needs to be stated that the reduction of urban congestion in Europe is partly due to the increasing sprawl of urban areas, which also considerably impacts daily travel and commuting times.

Table 4-3 also presents the summarised results for 85 urban areas in the US, provided by the Texas Transportation Institute's annual Urban Mobility Report (Schrank and Lomax 2006). The comparison shows that there is a much clearer development towards a rise in travel times in the US than it is observed for England. The situation of urban congestion in the US is considered very critical as all dimensions of congestion, which is severity, duration and geographical spread, show a steady growth and the ability to fight congestion by policy measures is considered limited. But the table shows that, given the parameters computed are comparable, the situation in European agglomerations is equally critical. For n in-depth comparison the travel time indicators must be computed using a unique methodology.

Further Information is obtained by the MVA Comparable World Cities Reports (Bennet 2005 and Dunnings 2005). Table 4-5 and Table 4-6 show the development of travel speeds on various networks of a sample of medium-sized and large world cities.

Table 4-5: Development of travel speeds in different medium-size cities

	Dublin	Lyon	Nottingham Preak period	Perth	Rome	Zurich
1991	24			45		36
1996	20*	28		46	29	
2000			25			
2001			26		26	
2002	13		25			
2003			27			
Total Growth	-45.8%		8.5%	1.3%	-10.0%	2.8%
Annual Growth	-5.4%		2.8%	0.3%	-3.5%	0.5%
Source: Dublin DTO (* 1997 data), Lyon Grand Lyon, Nottingham LTP, Perth Australian Bureau of Statistics, Rome City of Rome, Statistik Stadt Zurich						

Source: Bennet (2005)

Table 4-6: Development of travel speeds in different large world cities

Year	Barcelona		London AM Peak Only		Paris		Singapore	
	Ring road	Within city	Outer	Centre	Radials in inner suburbs	Radials in Outer Suburbs	Expres-sway	Within City
1999	59.8	19.9	29.31	16.1				
2002	58.9	20.2	27.22	15.9	62.5	60	66.7	24.8
2003	56.5	21.6	n/a	17.13	61.7	57.1	65.4	24.3

Source: Dunnings (2005)

The results of the country studies are presented in the table below

4.3 Rail transport

Giving a comprehensive picture of the quality of Europe's railway market is rather difficult as detailed punctuality figures by delay cause are treated as private information by many railway undertakings. Thus, only annual delay figures and peace-wise information on causes or on specific services is available. And even this information is to be treated with care as first, regular delays may be eliminated by the railway undertakings through adjusting time tables and second, the values often reflect the delay at the trains' final destination, which does in no way reflect the passengers or shipments affected.

Table 4-7: Railway punctuality figures EU and US

Country / company	Type of service	Margin	Punctuality	Year
US, Amtrax	Long-distance passenger Short-distance passenger	20 - 30 min. 10 - 20 min.	53 % 77 %	2003 2003
Germany, DB	Passenger	5 min.	95 %	2004
UK, all operators	Long distance sector London & south east Regional sector	10 min. 5 min. 5 min.	79 % 85 % 82 %	2005/06 2005/06 2005/06
France, RFF	South-east HSL North HSL Atlantic HSL	5 min. 5 min. 5 min.	82.2 % 87.1 % 86.3 %	2005 2005 2005
Poland, PKP	Passenger	5 min.	97.0 %	2004
Switzerland, SBB	Passenger	5 min.	92.3 %	2004
Finland, RHK	Inter-Urban Urban	5 min. 3 min.	97.6 % 90.0 %	2004 2004
Czech Republic	All passenger	5 min.	92.3 %	2005/1
Europe, UIRR	Intermodal freight	60 min.	72 %	2004
Germany, Railion	Freight	30 min.	90.6 %	2004
Finland	Freight	15 min.	94 %	2004

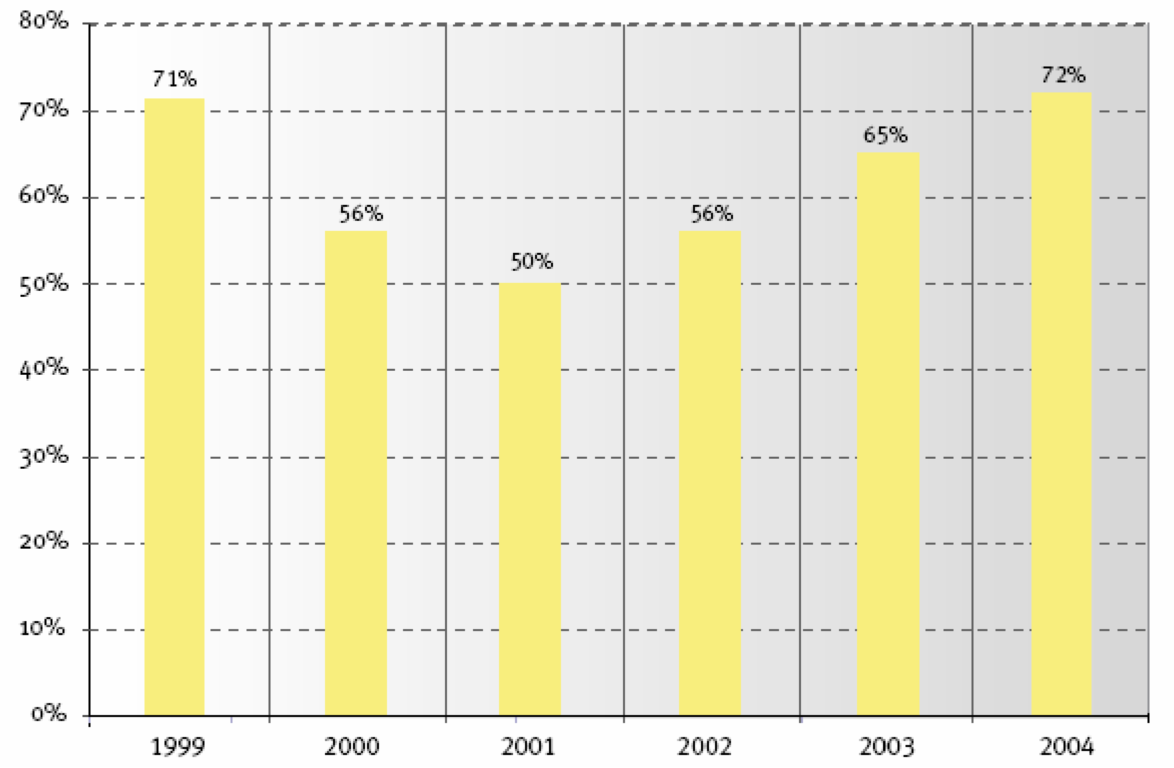
Source: Data from country reports in Annex 3

Further information on railway delays is available at the UNITE project. Table 4-8 presents total figures for 1998 for a selected number of countries.

Table 4-8: Total costs of railway delays - UNITE results 1998

Country	UNITE country accounts Delay costs 1998, million Euros
Germany	682
UK	185
France	133
Switzerland	65
Sweden	63
Netherlands	45
Greece	36
Belgium	32
Austria	25
Spain	10
Denmark	9

In international freight transport the data situation looks somewhat better. The "Joint Declaration on Quality in international conventional and combined railway freight traffic" signed by UIC/CER and FIATA/CLECAT on 15 April 2005 obliges the railway undertakings to report punctuality data using a common definition of the term "punctuality". According to CER (2005), the punctuality of intermodal rail-road trains in Europe was at 72% with a delay margin of one hour. In general, the report repeats that data is very fragmented and no unique definition of the term "punctuality" exists.



Source: CER (2005)

Figure 4-1: Punctuality of rail-road intermodal trains with 1 hour tolerance margin

Further details are given on the Brenner corridor, where punctuality reached 73% in 2004 and for individual companies. These results will be reported in the country sections below.

More detailed evidence on bottlenecks in the European rail network is given by respective analyses of the railway companies. In the UIC's EURAILINFRA study (UIC 2004) a number of corridors with current capacities, traffic forecasts and recommended investment measures is worked out.

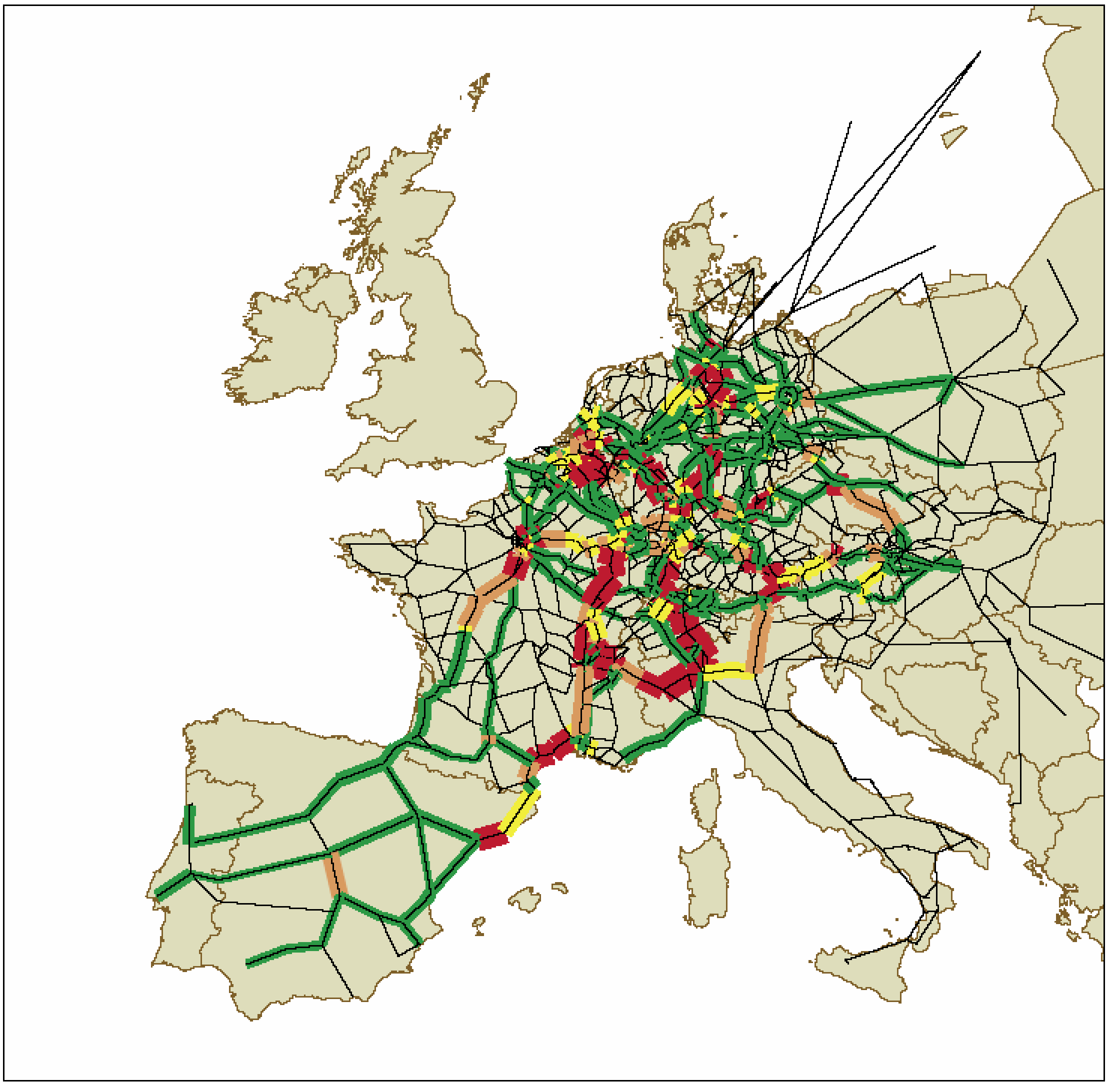
For investment planning the two most important columns are volume (Vol.), which is the effectively gained number of train paths per year, and efficiency (Eff.), which is the volume to investment ratio. For the congestion analysis, however, the traffic to capacity ratio is more interesting as will be explained below.

Table 4-9: Bottlenecks and recommended measures in the European rail network

Corridor	Bottleneck Site	Kind of Bottleneck (section or node)	Total daily traffic 2015 (paths/day)	Capacity without investment (paths/day)	Traffic / Capacity ratio	Proposed Solutions	Investment (mio Euro)	Scheduled for (Year)	Vol	Eff
1	Metz-Strasbourg	S	318	260	1,223	Reding-Strasbourg: local investmnet	20	2007	186.342	9.317
1	Bellinzona-Luino	S/N	212	90	2,356	Saturation of Nodes and line sections: partly double track; extention of Pino-Tronzano and Maccagno.	120	2015	549.000	4.575
1	Muhlhouse-Basle	N	290	260	1,115	3rd track	22	2008	83.976	3.817
1	Strasbourg-Mulhouse	S	324	260	1,246	Strasboourg-S□lestat: 3rd track	73	2008	210.875	2.889
1	Mannheim-Karlsruhe via Graben-Neudorf/Bruchsa	S	464	329	1,410	Upgrading line from Graben-Neudorf to Karlsruhe: Quadrupling	483	2015	607.500	1.258
1	Bern-Spiez	S/N	400	380	1,053	Saturation of Nodes and line sections: 3rd track ruti-Zollikofen; 3rd track Gumligen-Rubigen; reduction of headwa	104	2015	90.000	865
1	Mainz/Wiesbaden-Mannheim via Worms/Biblis/Bensheim	S	408	256	1,594	Inauguration new line Rhein/Main-rhein/Neckar for high speed traffic (250 Km/H); increasing capacity on the old line	1.772	2015	684.000	386
2	Bolzano-Trento	S	371	245	1,514	Bolzano-Bronzolo: quadruplicatior	1.500	2015	567.000	378
2	Trento-Verona	S	296	184	1,609	Automatic Block	1.500	2015	504.000	336
2	Fortezza-Bolzano	S	280	179	1,564	Fortezza-P. Gardena and Prato Tires-Bolzanc	1.500	2015	454.500	303
2	Rosenheim S.-Kufstein	S	276	268	1,030	Rosenheim S.-Kiefersfeld: Additional block signals	140	2012	29.923	214
1	Gallarate-Rho	S	286	248	1,153	Capacity bottleneck: 3rd track Galalrate-Rhc	887	2015	171.000	193
1	Rotkreuz-Erstfeld	S/N	376	312	1,205	Saturation of Nodes and line sections: New line "Berg lang	1.500	2015	288.000	192
2	Munchen-Rosenheim	S	308	283	1,088	Waldtrudering-Rosenheim: Third track and additional block signals	610	2015	112.500	184
1	Basel-Brugg	S/N	440	400	1,100	Saturation of Nodes and line sections: Connection F-D north of Basel; Bypass Hochrteim (new	1.100	2015	180.000	164
1	Luino-Laveno	S	149	133	1,120	Luino-Laveno: doubling	600	2015	72.000	120
1	Biasca-Bellinzona	S/N	340	320	1,063	Saturation of Nodes and line sections: bypass Bellinzona	1.000	2015	90.000	90
2	Innsbruck-Brenner	S	278	242	1,149	Brenner basis tunnel	2.000	2015	162.000	81
1	Basel-Olten	S/N	450	420	1,071	1. Cocnection F-D north of Base 2. Quadrupling (new line) Liestal-Olten	2.500	2015	135.000	54
1	Monza Milano Smistamento	S	301	293	1,027	Capacity bottleneck: doubling alternative route Seregno-Bergamo	1.000	2014	35.032	35
2	Brennero-Fortezza	S	273	264	1,034	Basis Tunnel	2.000	2015	40.500	20
1	Rho-Milano Smistamentc	S/N	286	278	1,029	Capacity bottleneck: AV/AC double track Torino-Milano-Veron	2.120	2010	25.447	12

Source: UIC (2004)

The estimated investment costs could be used to derive an avoidance cost indicator per country in case other information of sufficient quality is not available. However, as the investment plans presented here are biased by the interest of the railway companies to obtain high investment grants, more neutral sources should be used. Moreover, the proposed investment measures in many cases lead to considerable over-capacities and thus, the presented investment costs can hardly be used as approximations to opportunity costs of rail congestion. Nevertheless, Source: CER 2004 Figure 4-2gives a spatial overview of the capacity bottlenecks identified by UIC (2004) by presenting the corridors listed in Table 4-9 on the European rail network.



Source: CER 2004

Figure 4-2: Bottlenecks in the European rail network 2015 excluding investments

The comparison shows that US quality standards in rail punctuality are far below the high standards of European railway undertakings. But the distances in the US, and thus total travel times, are much longer in the US and Amtrax reports on mixed passenger and freight services, while EU punctuality figures are usually restricted to passenger services. Time series of punctuality presented in Figure 4-3 show that there might be high fluctuations in on-time arrivals and that short long-distance services are generally below the average of all services.

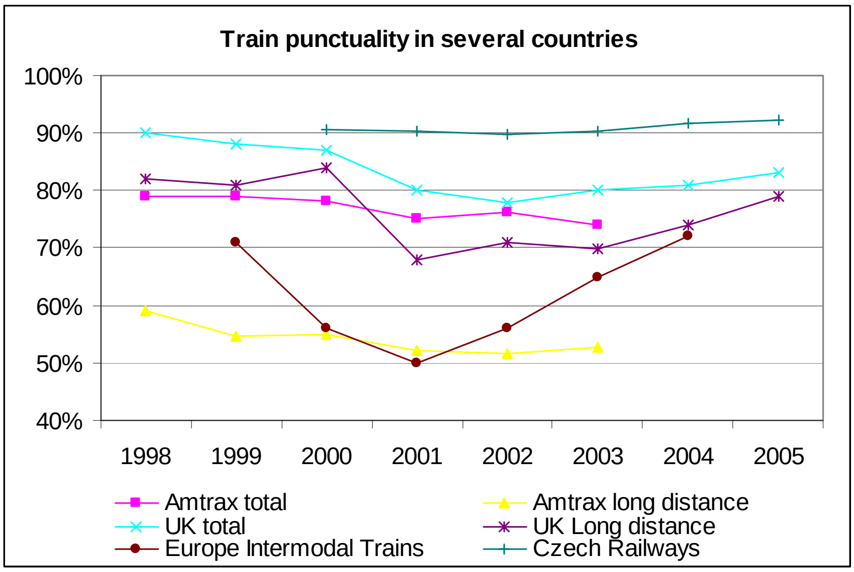


Figure 4-3: Time series of punctuality data for selected railway undertakings

5 Case Study European and US air transport

List of abbreviations

A&ATC	Airport and Air Traffic Control
AEA	Association of European Airlines
ATC	Air Traffic Control
ATM	Air Traffic Management
BAA	British Airports Authority
BTS	Bureau of Transport Statistics (US department of Transport)
CdG	Charles de Gaulle
CODA	Central Office for Delay Analysis (Eurocontrol)
EATMP	European Air Traffic Management Programme
ECAC	European Civil Aviation Conference
FAA	Federal Aviation Administration (USA)
NAS	National Aviation System (USA)
NMS	New Member States
USD	United States Dollars
USDOT	United States Department of Transport

5.1 Preliminaries

5.1.1 Objectives

The objective of this part of the COMPETE project is to assess the situation concerning capacity and congestion of the European air transport sector and compare it with the situation in the US. The analysis will have two stages:

- First, the general situation of the sector will be assessed, according to general data on delays on a large scale, this is, taken the European and US areas as unified systems. The work developed will focus on the analysis of the main trends, such as the general evolution of the main indicators on air traffic delays through the recent years and the interrelationships between regions (mainly for Europe). The main airports of the system will also be analysed following the evolution of the main variables concerning capacity and delays. The objective is to present a general picture of the situation of the main airports focused on the most relevant variables concerning capacity: passengers and cargo transported, causes of delay and evolution of delays over total flight operations;

- And second, a set of European and US airports will be selected for further analysis on congestion and capacity evolution according to several factors such as their importance for the air transport system, evolution of the main variables under analysis and peculiarities in the evolution and responses to congestion and delays. Fort this airports the analysis will include specific references to capacity shortages, evolution of delay causes and (if available) investment policy and other measures to fight congestion[1].

The analysis on airport capacity must be performed departing from the concept of airport congestion, measured in terms of flights delayed. The study of delayed flights combined with the evolution of total operations provides a good picture on the situation of airports concerning capacity available. Roughly, it can be said that airports operating near their maximum capacity will be more vulnerable to increases in the number of flights handled, and thus the rate of delayed flights over total operations will increase. On the other hand, airports with spare capacity will be able to cope with the increase of flights and reduced their ratios between delayed and total flights. The measurement of average minutes of delay will be also an important measure of airport capacity, complementing the analysis of the number of delayed flights.

5.1.2 Definitions, data sources and comparability terms

Previously to the analysis of airport capacity and flight delays, several concepts must be clarified in order to perform a sound assessment of the situation in Europe and the USA that allows the comparison of both scenarios.

First of all, the concept of "delay" applied to air transport operations is the measure of the difference between scheduled arrival or departure time of a flight and the real time that the operation takes place. A flight is classified as "delayed" both in Europe and the USA when the difference between scheduled and effective take off or landing differs in more than 15 minutes. More detailed databases, like the Eurocontrol Central Office for Delay Analysis (CODA) and the Bureau of Transport Statistics (BTS) in the USA account all significant delays in all operations, even for those flights not classified as "delayed".

The main data sources used for studying applied procedures of recording and processing data on air transport operation delays are the following:

1) **Europe**:

- The Association of European Airlines (AEA) provides annual reports on delays and punctuality for intra-European flights handled by the 27 more important airports (AEA 2000 to 2006). The reports provide information only for those flights officially classified as delayed, disaggregated by airline operating flights to and from the airports (this is, for arrivals and departures) and by delay reason;

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1 The inclusion of this type of information depended on the availability of the referred data from airport web sites, annual reports and accounts or other similar sources.

- Eurocontrol surveys the evolution of delays and congestion in the European Civil Aviation Conference (ECAC) through the **Central Office for Delay Analysis** (CODA), which is a service integrated in the European Air Traffic Management Programme (EATMP). CODA provides several statistics and reports on delays, being the most relevant for this study the Annual Report on Delays to Air Transport in Europe (Eurocontrol 2006).

2) **USA**:

- The main source for delay data is the US Department of Transport (USDOT) through the **Bureau of Transport Statistics** (BTS), that provides figures in different forms.
- **Federal Aviation Administration** (FAA) Performance and Accountability Reports, that provide information concerning punctuality and delays for the USA airport system.

5.1.2.1 Systematic of delay causes in Europe and the USA

The USA and Europe present the data on delays disaggregated by cause of the delay. The causes of delay are not the same in both areas, although this does not hinder the realisation of a robust comparison. The delay causes as accounted in Europe (AEA data classification) and the USA (BTS data classification) are the following:

1) **Europe (AEA categories)**:

- **Pre-flight operations**: generally refers to delays arising within the airline's own procedures or those of its handling agent previous to the flight, such as aircraft cleaning, baggage loading, fuelling, etc;
- **Maintenance/equipment failure**: related to technical problems arising with aircrafts or related equipment, a source of delay that can be classified as well as "airline source";
- **A&ATC delay**: airport and Air Traffic Control (ATC) delay, refers to delays either assigned by ATC (when a requested departure "slot" is not available), or to those arising from airport procedures, such as customs, immigration or security;
- **Weather**: unexpected weather conditions;
- **Late arrival**: reactionary delay to late arrival from incoming aircraft, that provokes delays in the operation of the subsequent scales in several airports, until it can be absorbed by the system.

2) **USA (BTS classification)**:

- **Air carrier delay**: delay was due to circumstances within the airline's control, such as maintenance or crew problems, aircraft cleaning, baggage loading, fuelling, etc;
- **Security delay**: caused by evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment and/or long waiting lines;

- **NAS delay**: National Aviation System delay, attributable to the national aviation system that refer to a broad set of conditions — non-extreme weather conditions, airport operations, heavy traffic volume, air traffic control, etc;
- **Extreme weather**: significant meteorological conditions (actual or forecasted) that, in the judgment of the carrier, delays or prevents the operation of a flight;
- **Late arrival of airplane**: previous flight with same aircraft arrived late, causing the present flight to depart late.

The equivalence between European and USA delay sources is fairly direct; differences are mainly arising from the allocation of the same type of delay categories to different types of sources. The main differences are the following:

- Air carrier delays according to the US definition are separated in two sources according to the European classification: pre-flight procedures and maintenance/equipment failure. The AEA statistics present this two categories as "airline delays" and, thus, the sum of them provides the same source of delays as the US "air carrier" category;
- Airport and Air transport Control (A&ATC) comprises all delays generated by airport procedures, such as customs and security, as well as ATC reasons (heavy traffic, slot not available, etc). These two main groups are separated in the USA statistics, but are fully equivalent to the European A&ATC source.

Table 5-1 resumes the different delay sources as provided by the AEA (e. g. AEA 2006) for Europe and by the Bureau of Transportation Statistics and the Department of Transport (e. g. DOT 2006) for the US, as well as the equivalence between them.

Table 5-1 – Sources of delay in Europe and the USA: equivalence

Europe: AEA delay categories	USA: DOT / BTS categories
Pre-flight procedures	Air carrier
Maintenance/equipment	
Airport and Air Traffic Control	Security
	National Aviation System
Weather	Extreme weather
Late arrival	Late arrival

Source: own elaboration from AEA and BTS data

The International Air Traffic Association (IATA) uses a system of roughly 100 delay codes, which is further aggregated by the Eurocontrol recording and reporting scheme to 18 detailed and 6 main causes. The system and the shares of delays for 2005 are presented in Table 5-2.

Table 5-2: Eurocontrol system of primary delay codes and results for 2005

eCODA cause	Description	IATA code	Share 2005
Airline	Passengers + Baggage	11-19	50 %
	Cargo + Mail	21-29	
	Aircraft + Ramp Handling	31-39	
	Technical + Aircraft Equipment	41-49	
	Aircraft Damage and Ops Computer Failure	51-59	
	Flight Operations	61-69	
	Other Airline-Related Causes	Other	
Airport	AFTM due to Restriction at Destination Airports	83	19 %
	immigration, Customs, Health	86	
	Airport Facilities	87	
	Restriction at Destination Airport	88	
	Restriction at Airport of Departure, with or ^	89	
En-Route	ATFM due to ATC En-Rte Demand Capacity	81	11 %
	ATFM due to ATC Staff/Equipment En-Route	82	
Security	Miscellaneous	98-99	4 %
Misc.	Mandatory Security	85	5 %
Weather	Weather	71-79	11 %
	ATFM due to Weather at Destination	84	

Source: Eurocontrol (2006)

5.1.2.2 Delay causes to be analysed

In principle, all delay sources must be analysed and accounted for as causes of delay in the air transport systems. All sources are important as can be considered as the indicator of a specific type of capacity shortage:

- **Air carrier delays**: considered as pre-flight procedures (fuelling, catering, cleaning, cargo or luggage handling, etc), failure of equipment or need for maintenance, represent the inability or failure of airlines to cope on due time with all pre-flight activities. When sustained through time, this can indicate a lack of capacity of airlines and handling agents for coping with the traffic levels. While due to their amount (50% of primary delay sources in 2005 in Europe according to Eurocontrol (2006)) airline delays are important for information purposes, their policy relevance is limited to state-owned airlines;
- **Airport and Air transport Control delays**: all airport procedures (security, customs, etc) and ATC issues (slot allocation for landing and take off operations, etc) can show the inability of the airports and related ATC systems to handle adequately with the level of passengers and cargo using the airport and the lack of capacity of the infrastructure to cope with the number of flight operations;
- **Late arrival of incoming aircraft (reactionary delays)**: this is not a delay caused by the airport receiving the aircraft but by a previous airport, but must be studied as can be considered a “systemic delay source”. The percentage of reactionary delays depends on how primary delay sources are made explicit and thus strongly varies be-

tween statistics. Values range around 35% of all delays according to the industry analysis in Eurocontrol (2006) but below 10% according to the AEA (2006). Eurocontrol (2006) further breaks down reactionary delays to primary delay causes as listed in Table 5-2). The high share of such delays indicates first, the high congestion of the system in general; and second, the inability of the system in absorbing the delay during daily operations throughout the system, driven by capacity shortages or by low delay recovery margins set by the airlines;

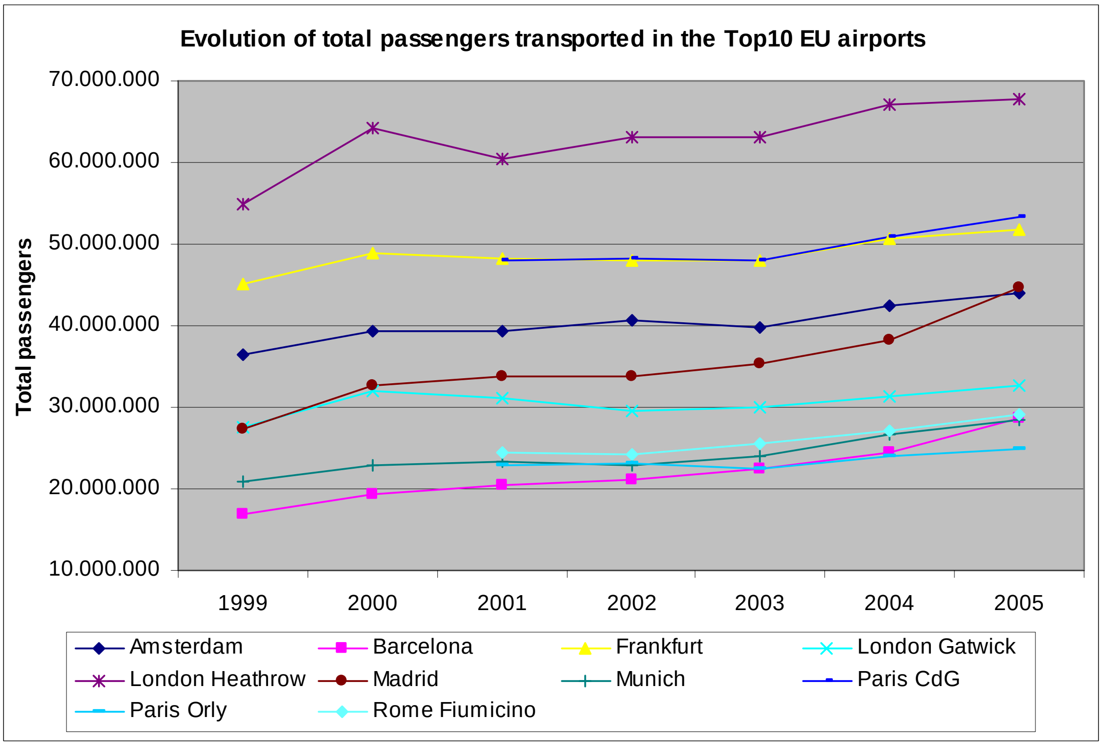
- Delays caused by **extreme weather** can be considered as exogenous, as they emerge quite randomly across the system. However, the percentage of these delays is quite small, varying both in the US (BTS 2006) and European air transport systems (AEA 2006) within an interval between 0.5% and 1.5% of total delayed flights (Eurocontrol (2006) reports 11% of delays due to weather conditions, including non-extreme conditions, which are, however, affecting air traffic management). Finally we opted for including extreme weather conditions in the analysis, as weather can be behind the delay of an aircraft with a late arrival, which is an important source of delays as well.

5.2 General situation of delays in Europe

5.2.1 Total delays to air transport

The European air transport sector is characterised by a quite steady growth during the last decade, with a brief recession provoked by the terrorist attacks on the 11th of September 2001[2]. Figure 5-1 presents the evolution of the total passengers transported by the Top10 2005 European airports since 1999. The 2001 crisis has different effects in the airports: in some as Madrid or Amsterdam it had little effect, but in others as the London airports it provoked a very significant reduction in the figures of passengers transported.

2 The air transport recession in and after 2001 was a world wide phenomenon. The USA air transport industry only recovered to the pre 2001 traffic levels in 2004.



Source: own elaboration from Eurostat data

Figure 5-1 – Evolution of the total passengers transported by the Top10 European airports

In aggregated terms, the industry represented in 2005 over 953 millions of passengers and over 12 million tonnes of freight transported by the EU25 Member States. Concerning passenger transport (see Table 5-3), roughly 40% was transported through the Top10 EU airports, in total 405 million passengers. The countries with the largest increases in passenger transported since 1995 were Austria (187%), Spain (135%), France (127%), Ireland (110%) and the UK (85%). From the NMS, although Eurostat does not provide data before 2004, it can be highlighted the steep growth rate during the most recent years: between 2004 and 2005, total passengers transported grew in Latvia 77.3%, in Slovakia 46.4%, in Lithuania 44.3% and in Estonia 40.6%. Taken as a whole system, these figures present a fast growing sector in Europe, especially in the NMS.

Table 5-3 – Evolution of the total passengers transported by the EU25 Member States

	Absolute values				Percentage of growth		
	1995	2000	2004	2005	1995 2000	2000 2004	2004 2005
EU25			882.295.647	953.191.717			8,0%
Belgium	12.505.217	21.594.842	17.468.503	17.813.943			2,0%
Czech Rep.			9.950.314	11.265.764			13,2%
Denmark			21.005.796	22.172.778			5,6%
Germany	90.941.123	120.666.471	135.850.284	145.977.422		12,6%	7,5%
Estonia			990.776	1.393.105			40,6%
Greece	19.313.135	30.708.227	29.509.262	30.798.527		-3,9%	4,4%
Spain	55.025.894	109.971.151	129.771.378	147.999.020	99,9%	18,0%	14,0%
France	44.652.838	96.366.913	103.015.756	107.955.149	115,8%	6,9%	4,8%
Ireland	9.781.040	16.685.252	20.851.353	24.254.298	70,6%	25,0%	16,3%
Italy	44.843.446		81.212.757	87.494.907			7,7%
Cyprus			6.421.198	6.782.277			5,6%
Latvia			1.056.041	1.872.040			77,3%
Lithuania			994.161	1.434.241			44,3%
Luxembourg			1.509.069	1.538.152			1,9%
Hungary			6.444.548	8.048.760			24,9%
Malta			2.790.121	2.762.177			-1,0%
Netherlands	25.544.282	40.626.191	44.493.696	46.433.037	59,0%	9,5%	4,4%
Austria	5.527.894	7.677.070	18.296.612	19.684.822	38,9%	138,3%	7,6%
Poland			6.091.886	7.080.325			16,2%
Portugal	11.299.367	16.228.543	18.422.969	20.272.160	43,6%	13,5%	10,0%
Slovenia			1.046.162	1.217.167			16,3%
Slovakia			1.080.945	1.582.978			46,4%
Finland		10.721.453	11.785.244	12.348.113		9,9%	4,8%
Sweden			19.957.013	20.997.169			5,2%
UK	100.971.029	162.339.334	192.279.803	204.013.386	60,8%	18,4%	6,1%

Source: own elaboration from Eurostat data

The picture for freight transport (see Table 5-4) is different, presenting a double trend of general growth until 2000 and a recession in several countries between 2000 and 2005. Again the NMS present high rates of growth, especially the Baltic Republics, between 2004 and 2005: Lithuania 84.8%, Estonia 40.6% and Latvia 77.3%. Also Slovakia presents a very high growth for that period, 46.4%. For the former EU15 Member States, the highest growth rates are those for Austria (200%), Spain (108%) and the UK (52%).

Table 5-4 - Evolution of the total freight (tonnes) transported by the EU25 Member States

	Absolute values				Percentage of growth		
	1995	2000	2004	2005	1995 2000	2000 2004	2004 2005
EU25			11.811.887	12.118.474			2,6%
Belgium	426.233		663.058	694.523			4,7%
Czech Rep.			57.512	56.259			-2,2%
Denmark			7.928	7.465			-5,8%
Germany		2.364.765	2.786.025	3.005.967		17,8%	7,9%
Estonia			4.998	9.739			94,9%
Greece		134.562	111.600	105.502		-17,1%	-5,5%
Spain	243.885	478.953	520.503	536.329	96,4%	8,7%	3,0%
France	1.034.330	1.170.979	1.485.506	1.476.721	13,2%	26,9%	-0,6%
Ireland	60.910	77.258	62.163	89.356	26,8%	-19,5%	43,7%
Italy	534.703		783.800	754.417			-3,7%
Cyprus			37.190	39.220			5,5%
Latvia			8.326	15.428			85,3%
Lithuania			5.183	9.580			84,8%
Luxembourg			616.583	624.803			1,3%
Hungary			60.432	55.472			-8,2%
Malta			15.948	14.796			-7,2%
Netherlands	982.547	1.267.623	1.511.957	1.550.736	29,0%	19,3%	2,6%
Austria	45.827	65.941	159.653	181.533	43,9%	142,1%	13,7%
Poland			31.423	31.130			-0,9%
Portugal	122.082	158.100	123.309	129.516	29,5%	-22,0%	5,0%
Slovenia			4.983	4.549			-8,7%
Slovakia			8.197	4.069			-50,4%
Finland		101.423	123.493	119.569		21,8%	-3,2%
Sweden			150.957	150.957			0,0%
UK	1.584.054	2.274.057	2.471.160	2.450.838	43,6%	8,7%	-0,8%

Source: own elaboration from Eurostat data

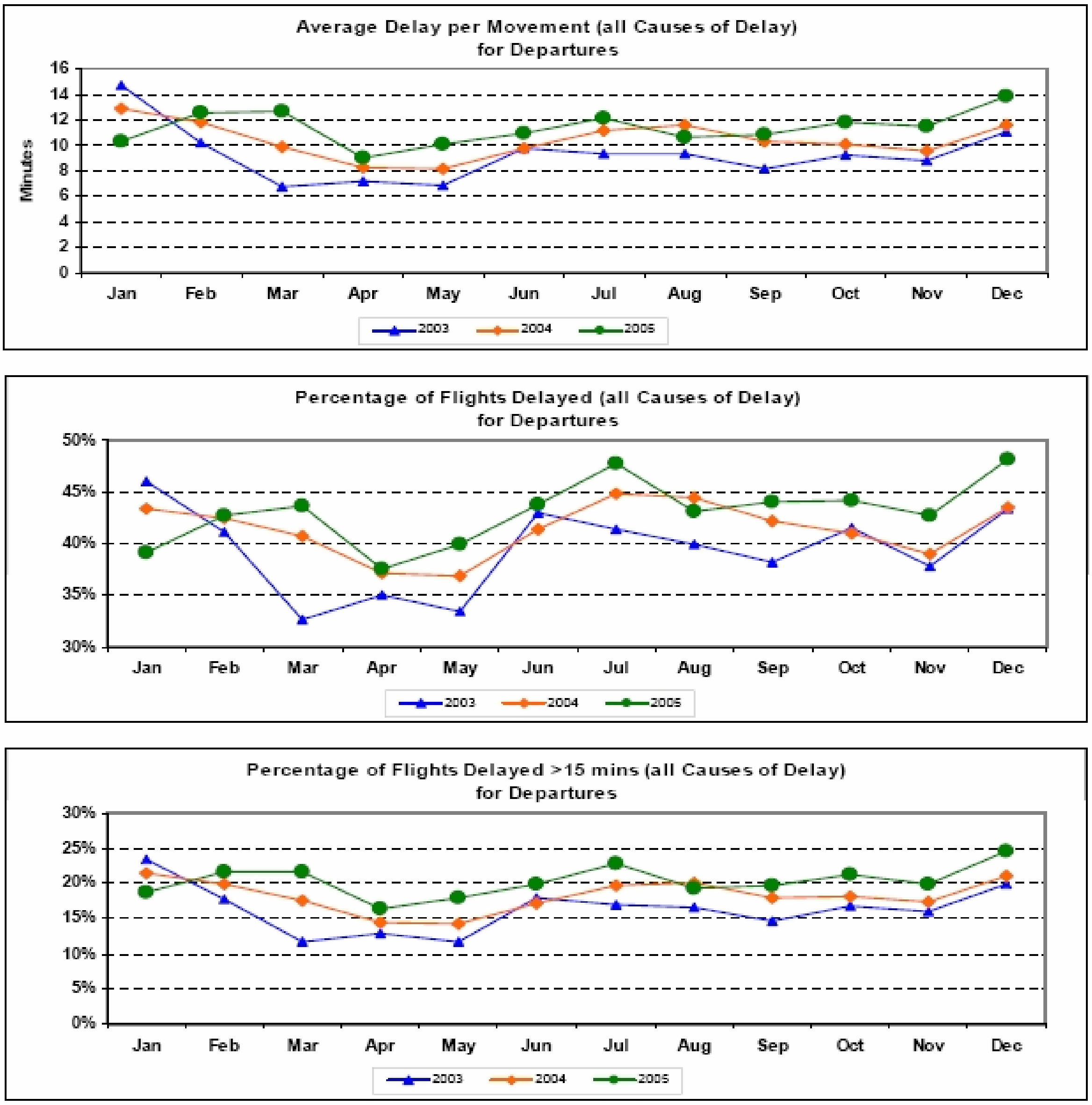
The scenario presented by the evolution of the total passengers and freight transported is one of a highly dynamic industry, where large investments have been undertaken in the last decades to cope with the demand growths. According to Eurocontrol CODA data[3], the total number of flights in the ECAC area during 2005 surpassed the 9 millions, with significant increases in all months compared with 2004 and a total average growth of 4% in operations. Concerning delays, the main figures of the period are the following: the total number of flights with some delay increased in absolute terms in 1.3% for arrivals and 1.6% for departures, the total number of flights considered as "officially delayed"[4] was reduced by 1.9% for arrivals and 5.7% for departures, and finally the average delay per movement increased by 3.4% for arrivals and 8.9% for departures. In few words, the ECAC region presents an increase of delayed flights smaller than the total increase in flights, which describes a situation of aggregate spare capacity of the system that even allows a significant reduction in the absolute value of operations with delays over 15 minutes. However, the average delay of all operations has grown substantially, which can be an indicator for a certain limitation of the systemic aggregate spare capacity. The figures indicate that air traffic control, the airports and the airlines have managed to distribute the load of overall growing delays more equitably

[3] Eurocontrol CODA report on Delays to Air Transport in Europe (Digest-Annual 2005).

[4] This is, those fligths with a delay over 15 minutes over their arrival/departure schedule.

to flights, such that in total the number of severe delays could even be reduced. This fact highlights the importance of an efficient flight operation environment.

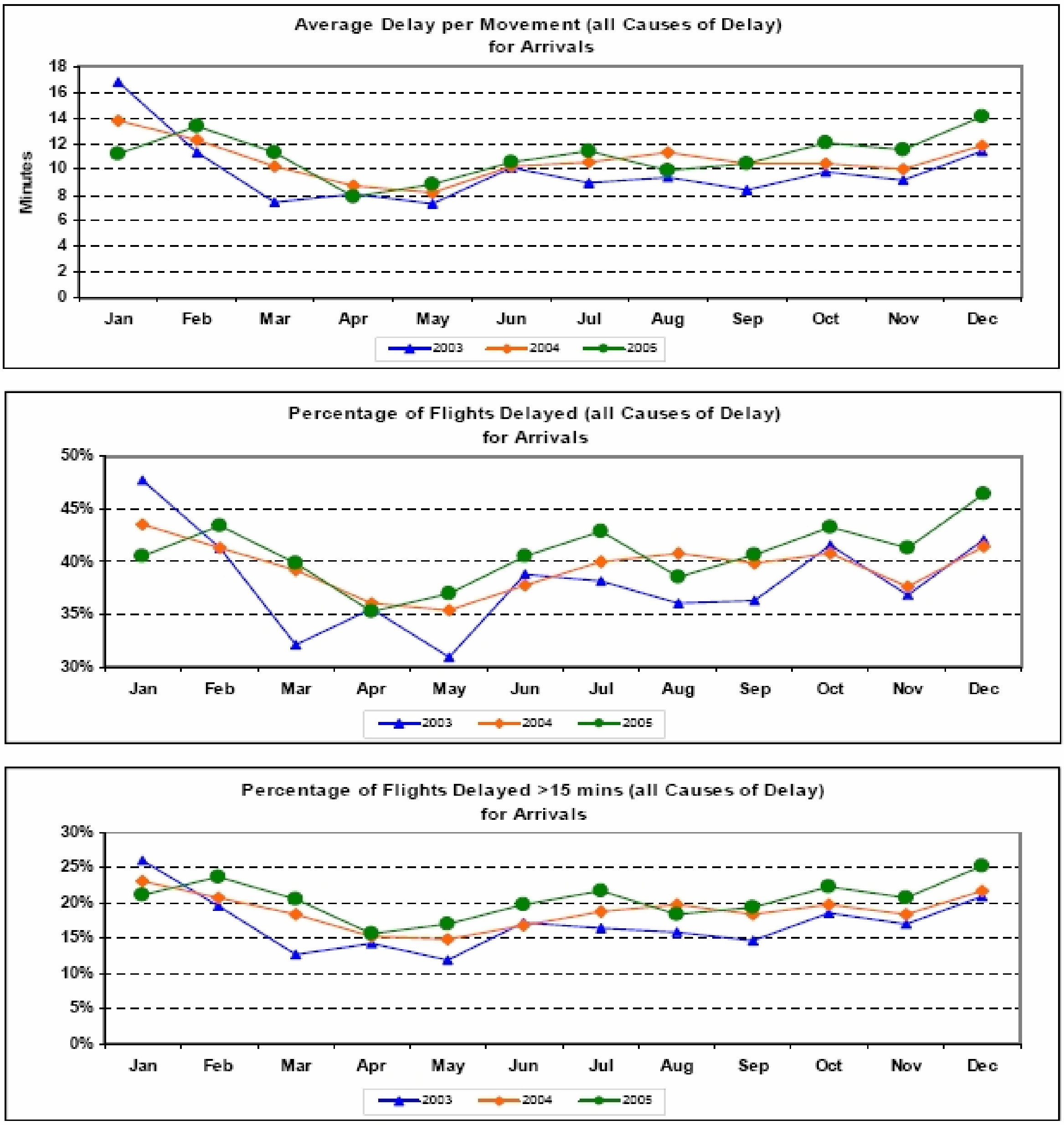
In historical terms, the CODA reports focus mainly in the evolution of the delay caused by Air Traffic Flow Management reasons in the ECAC area. This is, on delays directly caused by the European air traffic management system. Nevertheless, since 2003 CODA reports also provide figures on total delays disaggregated by type of operation (arrivals and departures). Concerning departures, Figure 5-2 provides the evolution of several parameters concerning delays and capacity. First of all, delayed departures have grown since 2003 every month to an average annual rate of approximately 45% of total departures. Delays over 15 minutes (the "official delays") have grown also during the same period to an annual average percentage over total departures of approximately 20%, slightly over the 2004 numbers. The average delay in minutes has also grown to approximately 12 minutes.



Source: Eurocontrol CODA report on Delays to Air Transport in Europe, 2005

Figure 5-2 – Monthly evolution of delayed departures (2003-2005)

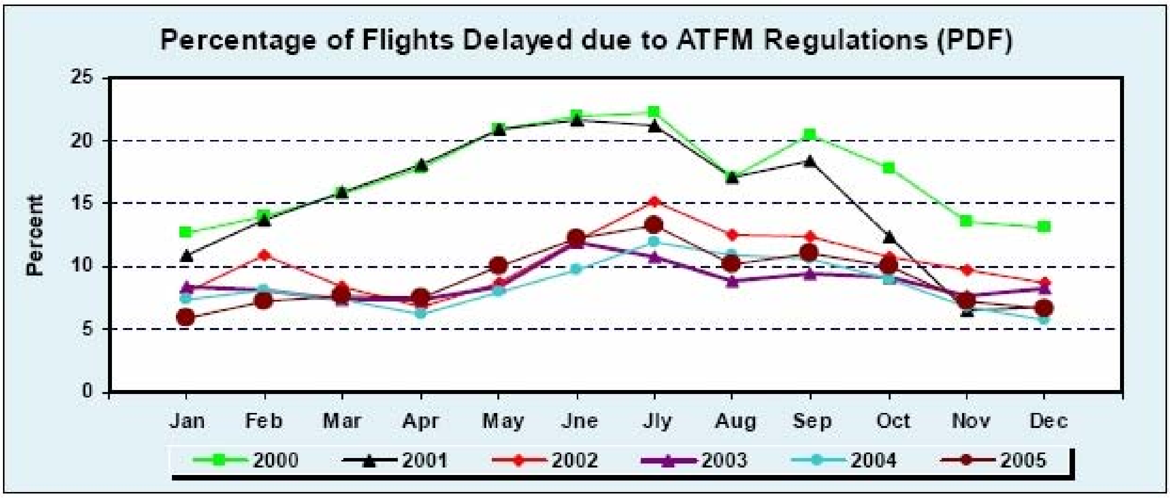
The evolution of arrivals is quite similar for the same period, as presented in Figure 5-3, with percentage of delayed arrivals, arrivals delayed over 15 minutes and average delay growing in comparison to 2004 and 2003. However, it must be taken into account that the interannual growth of total flights of 4% is higher than the increases in the percentage of flights delayed. Thus, total flights are growing more rapidly than delayed flights, which means that airport and ATFM capacity in the ECAC area can cope with the flight operation increase.



Source: Eurocontrol CODA report on Delays to Air Transport in Europe, 2005

Figure 5-3 - Monthly evolution of delayed arrivals (2003-2005)

As introduced previously, the CODA reports focus mainly on the evolution of the ATFM delays, directly under the responsibility of Eurocontrol. All variables affecting air traffic management and control are accounted for in this category: en-route weather, ATC staffing and equipment, overflight restrictions, airport safety procedures, etc. Figure 5-4 presents the percentage of total operation in the ECAC area subject to delays provoked by the ATFM system. The figure has decreased since 2001, being the numbers of 2005 amongst the lowest of the period under analysis. This means that the ATFM system has turned more efficient in managing the European flight operations and has been inducing less delay in the system during the last decade. An important issue of the monthly distribution of delays is that the ATFM has succeeded in reducing delays in the peak months during the summer, reducing the difference between peak and off-peak months throughout the year.



Source: Eurocontrol CODA report on Delays to Air Transport in Europe, 2005

Figure 5-4 – Monthly evolution of flights delayed due to ATFM (2000-2005)

5.2.2 Geographical spread of aviation delays

An important piece of information provided by the CODA reports is the distribution per region of delays for intra-European flights presented in flow diagrams. These diagrams allow to survey the evolution thorugh time of the 10 most dense air traffic flows as well as their level of delay. In the following pages we present the CODA traffic flow diagrams from 2002 to 2005 (see Table 5-7 and Figure 5-5).

Since the end of the 90s, the most dense and most congested regional flows (in terms of delays cumulated) have experienced a change, mainly with the shift from North-South Europe corridors to North-Central Europe corridors. Table 5-5 provides a brief resume of the information concerning the most dens and delayed regional flows in terms of the issuer/recipient character of a region. The CODA diagrams include only the 10 most intense traffic flows that surpass the 12.000 annual flights. The main characteristics that can be highlighted from the CODA diagrams are the following:

- London and UK & Ireland airports are key players as recipients and issuers of operations, with some of the densest and more congested inbound and outbound flows during the period. Of special importance are the outbound flows to Greece and Cyprus;

- Paris airports are net recipients of the system, especially from the UK & Ireland airports and some other continental regions, due to its increasingly important role as major European hubs;
- Greece and Cyprus airports are net recipients, due to their role of holiday destinations;
- Northern Italy sustains strong outbound flows, mainly to Paris and London airports;
- Austria, Slovenia and other Central European Countries have emerged recently as (mainly) issuers of flows, coinciding with the large growth of air transport in the area (see Table 5-3 and Table 5-4).

In terms of the evolution of delays in the CODA regional flows, Table 5-6 presents the average delay minutes and average percentage of delayed flights between 2002 and 2005. For the 10 most important CODA flows, the annual average percentage of delayed flights decreased since 2002 with a recovery in 2005, just the same behaviour as the annual average delay measured in minutes. Both variables increased in 2005 to similar values to that of 2003.

Table 5-5 – Resume of the CODA diagrams information in terms of issuer/recipient regions presenting higher densities and delays in their flows

	2002	2003	2004	2005
UK & Ireland	Issuer & Recipient	Issuer	Issuer	Issuer & Recipient
Nordic States DK/FI/NO/SE	Issuer	Issuer	Issuer	
London Airports	Issuer & Recipient	Recipient	Issuer & Recipient	Issuer & Recipient
Paris Airports	Recipient	Recipient	Recipient	Recipient
Balearics & Spain East	Issuer & Recipient			
Iberian Peninsula & Canarias ES(West)/PT/Canarias	Issuer			Issuer
Greece & Cyprus GR/CY	Recipient	Recipient	Recipient	Recipient
Italy North	Issuer	Issuer	Issuer	Issuer & Recipient
Germany West	Issuer	Issuer & Recipient		
Switzerland		Issuer & Recipient	Issuer & Recipient	
France South East		Issuer		
BENELUX BE/NE/LU		Issuer	Issuer	
Austria & Slovenia			Issuer & Recipient	Recipient
Central Europe SK/HU/BG/HR/BA/LY/AL/FYROM			Issuer	Issuer

Source: own elaboration from Source: Eurocontrol (2003 to 2006)

Figure 5-5 to ***Fehler! Verweisquelle konnte nicht gefunden werden.***

Table 5-6 – Evolution of the average delay (minutes) and percentage of delayed flights in the main CODA regional flows

	2002	2003	2004	2005
Percentage of delayed flights	31,7%	26,7%	25,5%	26,8%
Average delay per flow	7,78	5,49	5,09	5,56

Source: own elaboration from Eurocontrol CODA data

As a resume, it can be said that the 10 most important CODA regional flows are quite constant though time in what respect to the main airports of the flows, which are some of the large European hubs: London airports and Paris airports[5]. The flows also follow the already mentioned trend of reduction of the total delays and, although the account of delay time is not undertaken only for "officially delayed" flights, the reduction in 2 minutes across the systems is an important sign of the improvement of capacity in a context of continuous growth of operations and transported passengers and goods (see Table 5-3 and Table 5-4).

The CODA diagrams are synthesised in Table 5-7, that presents in a more readable way the evolution of 10 main the regional flows in terms of volume of flights, share of delayed flights and average delay per flight. As presented previously in Table 5-6, there is an overall trend for reduction of delay time and percentage of delayed flights. In more detail, the evolution of the three variables is as follows:

- Number of flights per flow: in general the trend has been to increase the number of flights per flow between 2002 and 2003 and a slight reduction between 2004 and 2005. It is also worth noting the rise of new regional flows (Central Europe and Austria & Slovenia, for example);
- Percentage of delayed flights: the trend was of general reduction during the period in almost all flows, even in those years with larger increase in the number of flights, with a slight increase in delays in some flows between 2004 and 2005;
- Average delay: as for the percentage of delays, the trend was of reduction with a slight increase in 2005.

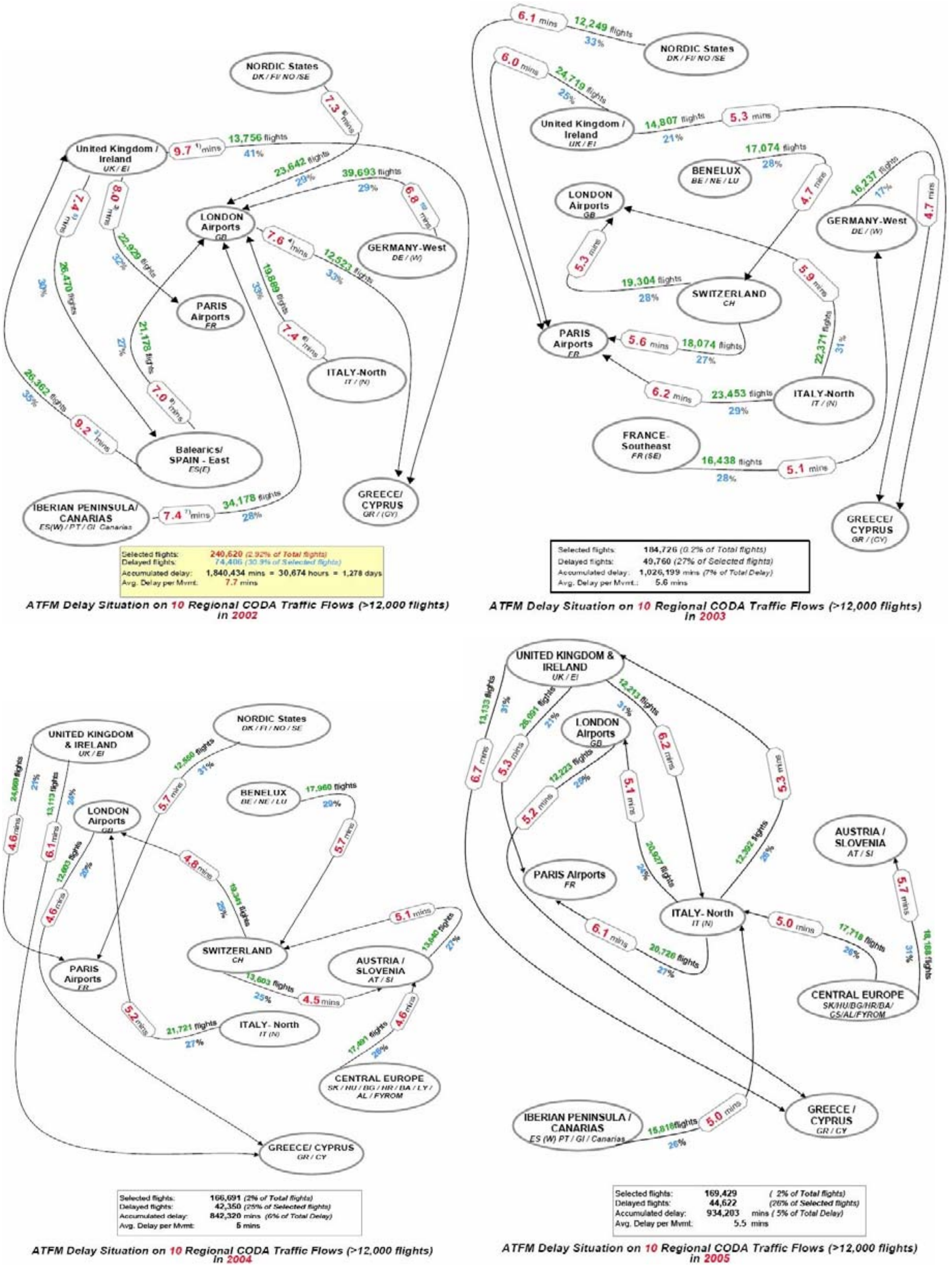
5 CODA diagram data are not disaggregated by airport, but quite likely the main flows are generated/attracted by Heathrow and Charles de Gaulle.

Table 5-7 – Evolution of the 10 main CODA regional flows

Flight region	Total flights per flow				Share of delayed flights				Average delay (minutes)			
	2002	2003	2004	2005	2002	2003	2004	2005	2002	2003	2004	2005
UK & Ireland to												
Greece / Cyprus	13.756	14.807	13.113	13.133	41%	21%	24%	31%	9,7	5,3	6,1	6,7
Paris airports	22.929	24.719	24.669	26.091	32%	25%	21%	21%	8,0	6,0	4,6	5,3
Italy North	13.756			12.213	41%			31%	9,7			6,2
Balearic-Spain East	26.470				30%				7,4			
London to												
Greece / Cyprus	12.523		12.603	12.223	33%		20%	25%	7,6		4,6	5,2
Nordic States to												
London	23.642				29%				7,3			
Paris		12.249	12.550			33%	31%			6,1	5,7	
Benelux to												
Switzerland		17.047	17.960			28%	29%			4,7	5,7	
Switzerland to												
London		19.304	19.341			28%	25%			5,3	4,8	
Paris		18.074				27%				5,3		
Austria / Slovenia			13.603				25%				4,5	
Austria/Slovenia to												
Switzerland			13.640				27%				5,1	
Italy-North to												
UK & Ireland				13.392				26%				5,3
London	19.889	22.371	21.721	20.927	33%	31%	27%	24%	7,4	5,9	5,2	5,1
Paris Airports		23.453		20.726		29%		27%		6,2		6,1
Central Europe to												
Italy North				17.718				26%				5,0
Austria/Slovenia			17.491	18.188			26%	31%			4,6	5,7
Iberian / Canary to												
London	34.178				28%				7,4			
Italy North				15.818				26%				5,0
Balearic-Spain East to												
UK & Ireland	26.362				35%				9,2			
London	21.178				27%				7			
France Southeast to												
Germany West		16.438				28%				5,1		
Germany West to												
Greece / Cyprus		16.237				17%				4,7		

Source: Eurocontrol (2003, 2004, 2005, 2006)

Table 5-7 reveals that there is no clear trend in how the top-10 traffic relations within the European air space and the delays on these routes develop. Across all routs a share around 30% of flights is delayed by ATM measures causing an average delay around 6 minutes per flight. The four graphs in Figure 5-5 illustrate the contents of Table 5-7 by a geographical scheme.

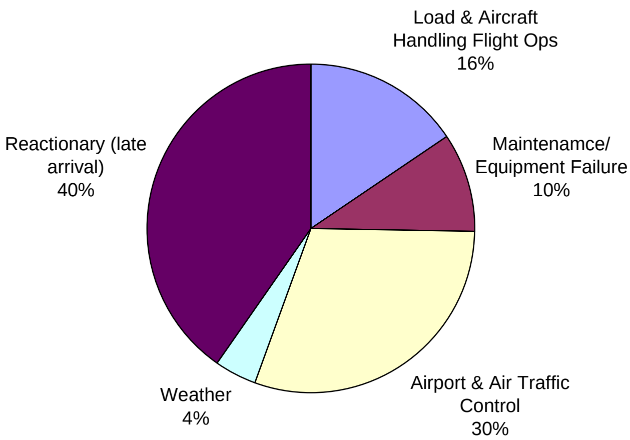


Source: Eurocontrol (2003 to 2006)

Figure 5-5 – CODA traffic flow diagram for 2002 to 2005

5.2.3 Aviation delays by cause

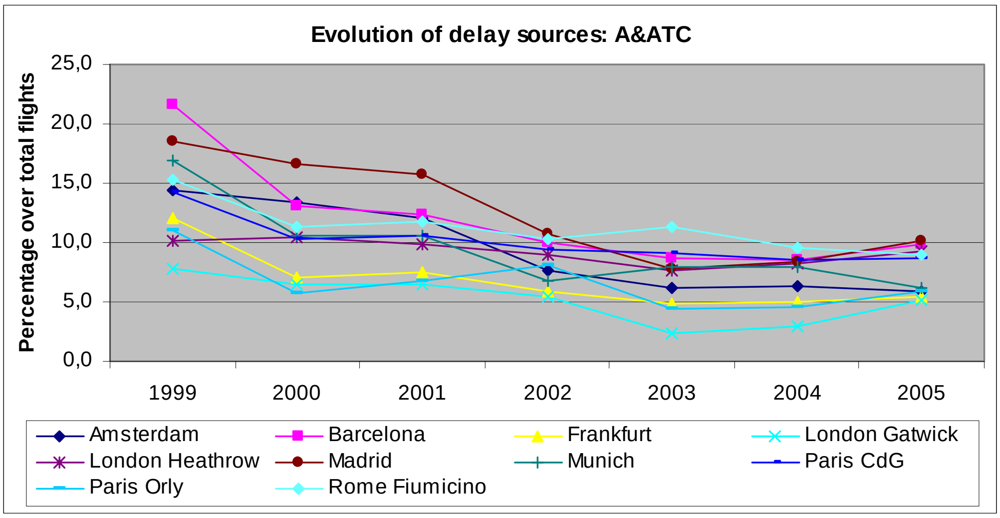
The CODA analysis must be complemented with the analysis of the 5 delay sources as presented by the AEA annual reports on punctuality for the 27 European major airports. As presented in the beginning of this analysis, the delay sources are: pre-flight procedures, maintenance/equipment failure, Airport and Air Traffic Control (A&ATC), weather and late arrival of incoming aircraft. The AEA data refer only to intra-European flights, more precisely to departures. The comparability between AEA data and USA data was explained previously in this report. The analysis is focused in the evolution of the delay sources in the Top10 European airports between 1999 and 2005. Figure 5-6 gives a rough overview of delay causes at the top 27 airports in 2005 according to AEA (2006). The percentages relate to delayed flights.



Source: Data from AEA (2006)

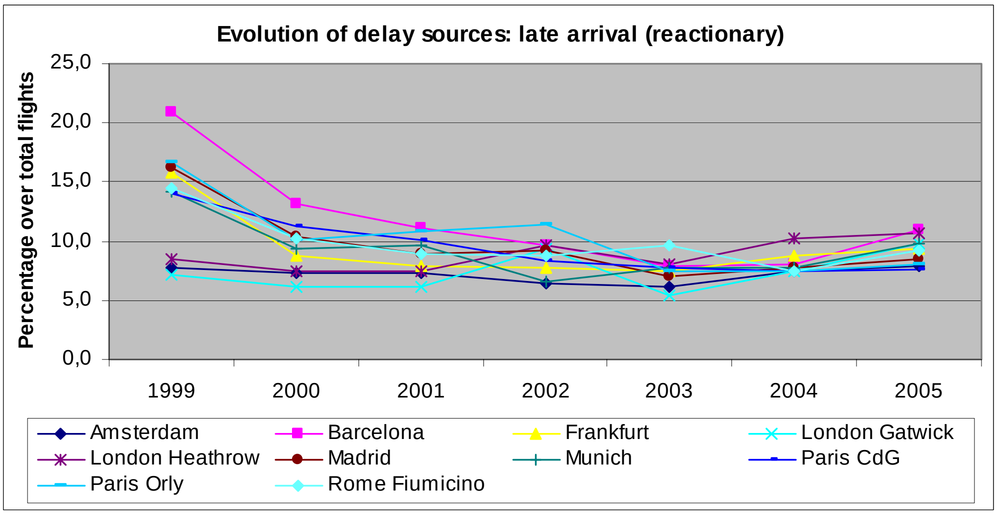
Figure 5-6: Distribution of main delay causes at the top 27 European airports

The two main sources of delay in Europe are A&ATC and late arrival of incoming aircraft. Nowadays both account for figures included in an interval between 5% and 10% of total flights. The figures are much more concentrated than in 1999, a year that must be taken cautiously according to AEA due to the important disruption caused by the restrictions to air traffic derived from the Kosovo conflict. Figure 5-7 and Figure 5-8 present the evolution of both delay sources across the Top10 European airports. Concerning the A&ATC, the 2005 worst performers are Madrid, Rome, Barcelona and Paris CdG. The 2005 best performer were London Gatwick, Munich, Frankfurt, Amsterdam and Paris Orly. Here, the percentages relate to total flights.



Source: own elaboration from AEA data

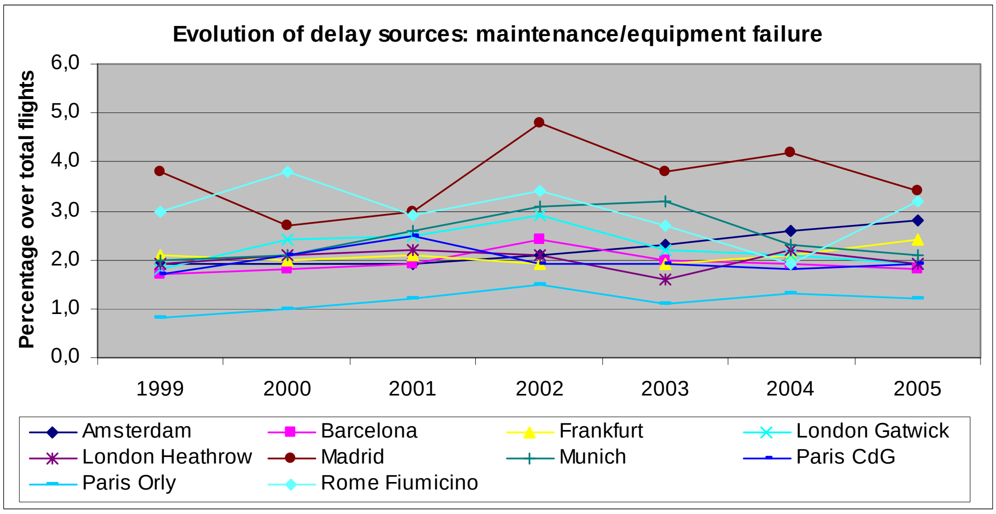
Figure 5-7 – Delay sources evolution in Europe: Airport and Air Traffic Control



Source: own elaboration from AEA data

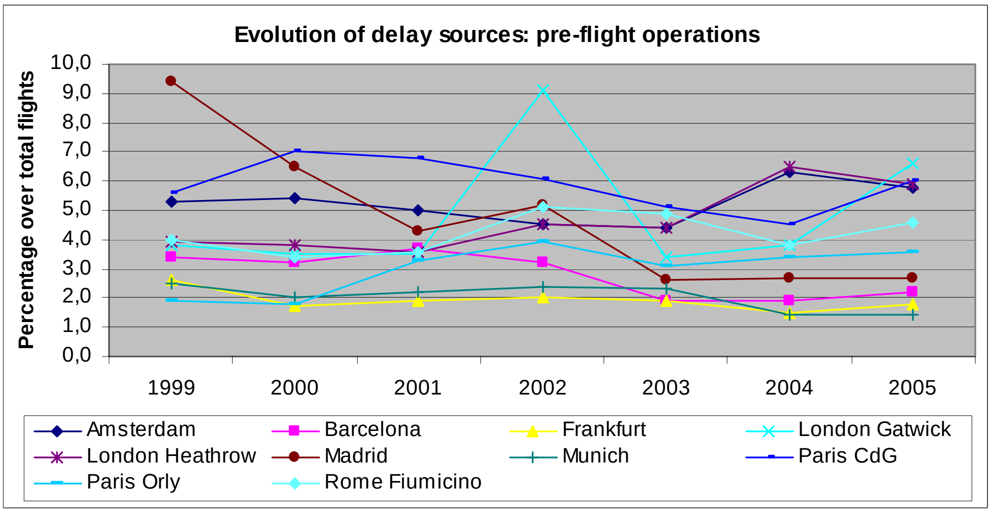
Figure 5-8 – Delay sources evolution in Europe: late arrival of incoming aircraft

The 2 delay sources that can be classified as “airline sources” are maintenance/equipment failure (see Figure 5-9) and pre-flight operations (see Figure 5-10). The percentage of delayed flights caused by both sources has been quite stable during the period, varying between 1% and 4% for maintenance/equipment failure (with some outlayers by Madrid over the maximum) and between 1% and 7% for pre-flight operations (with outlayers over the maximum by Madrid and Gatwick).



Source: own elaboration from AEA data

Figure 5-9 – Delay sources evolution in Europe: maintenance/equipment failure



Source: own elaboration from AEA data

Figure 5-10 - Delay sources evolution in Europe: pre-flight operations

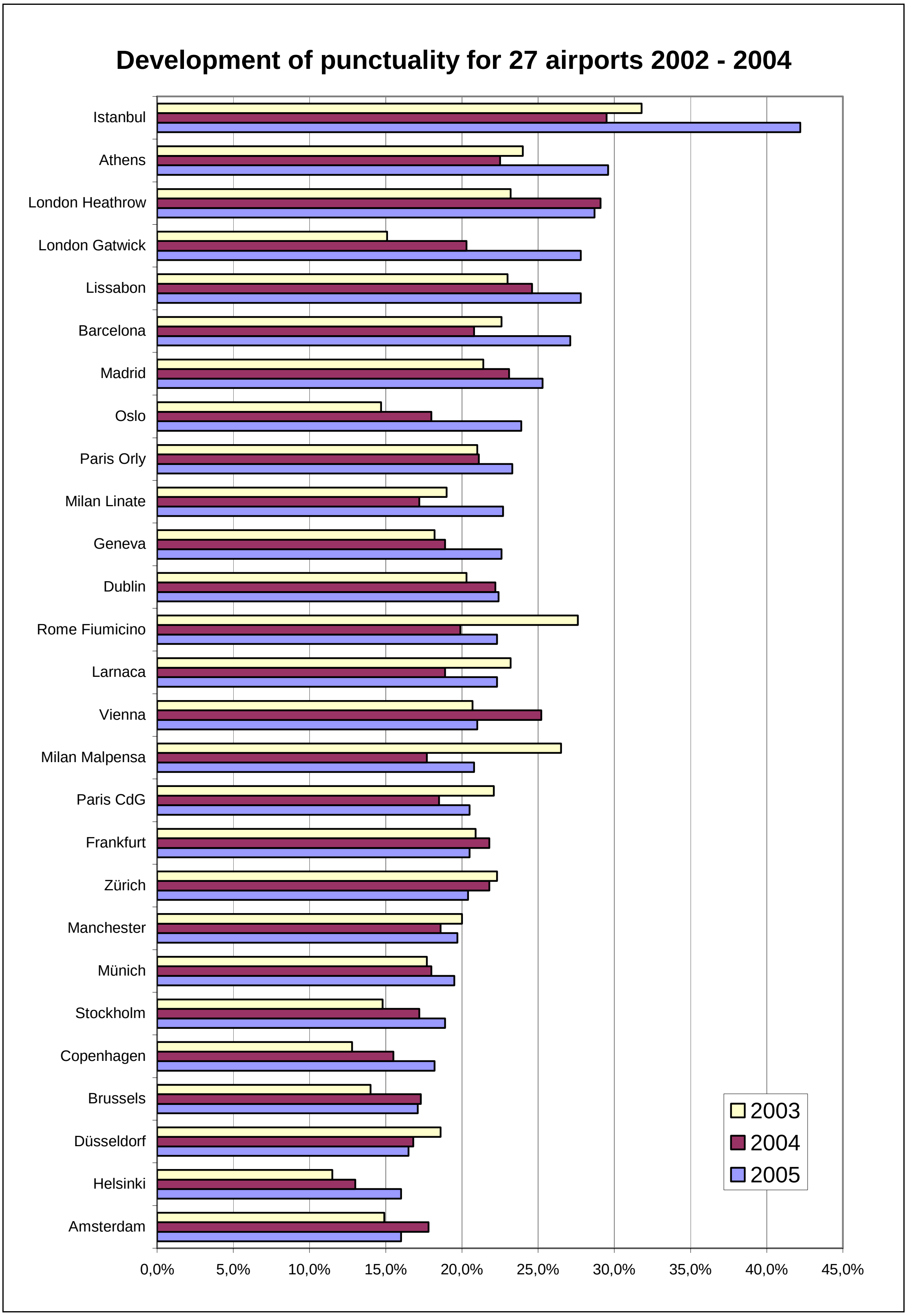
In their annual punctuality reports AEA ranks the 27 largest airports in Europe according to the share of delayed flights. Per airport the reports give average annual arrival and departure delays by airline and the mix of delay causes for the airport in total (Table 5-8 and Figure 5-11).

Table 5-8: AEA punctuality rates and delay causes 2003

Airport	Punctuality ranking 2003 *	% of flights delayed 2003 **	Average delay 2003 (min.) ***	Reason of delay 2003 (in % of flights) **				
				Load & Aircraft Handling Flight Ops	Maintenamce/ Equipment Failure	Airport & Air Traffic Control	Weather	Reactionary (late arrival)
Düsseldorf	1.	13,8%	39,4	0,8%	1,4%	5,1%	0,8%	5,7%
Helsinki	2.	15,5%	36,8	2,0%	1,9%	5,3%	1,4%	5,0%
Brussels	3.	15,7%	41,6	1,6%	1,0%	5,4%	0,6%	7,0%
Copenhagen	4.	16,1%	38,8	3,8%	3,5%	2,7%	0,6%	5,7%
Oslo	5.	16,2%	39,0	3,0%	2,2%	3,0%	0,4%	7,5%
Stockholm	6.	16,7%	37,5	3,3%	1,6%	4,4%	1,1%	6,5%
Geneva	9.	19,6%	41,9	1,8%	0,8%	5,2%	1,5%	10,3%
Larnaca	8.	19,6%	54,1	3,9%	3,9%	4,5%	0,1%	7,4%
Paris Orly	7.	19,6%	51,6	3,6%	1,2%	5,9%	0,8%	8,1%
Lissabon	10.	20,1%	42,6	1,8%	1,2%	6,7%	0,1%	10,2%
Frankfurt	12.	20,2%	37,0	1,8%	2,4%	5,5%	1,4%	9,4%
Milan Linate	11.	20,2%	41,6	2,1%	1,0%	8,9%	1,3%	6,9%
Manchester	14.	21,3%	42,8	3,2%	2,1%	5,6%	0,8%	9,5%
Zürich	13.	21,3%	34,7	1,4%	1,3%	7,2%	1,4%	10,0%
Münich	15.	21,5%	39,8	1,4%	2,1%	6,2%	2,0%	9,8%
Milan Malpensa	16.	23,0%	44,6	3,7%	2,8%	7,4%	1,1%	8,1%
Amsterdam	18.	23,3%	43,9	5,8%	2,8%	5,9%	0,9%	7,9%
Vienna	17.	23,3%	32,1	3,5%	2,3%	6,6%	1,1%	10,1%
Dublin	19.	24,1%	40,8	4,4%	1,5%	7,1%	0,4%	10,7%
London Gatwick	20.	24,2%	31,8	6,6%	1,9%	5,2%	1,0%	9,8%
Paris CdG	21.	25,0%	41,2	6,0%	1,9%	8,7%	0,8%	7,6%
Barcelona	22.	25,5%	43,6	2,2%	1,8%	9,8%	0,6%	10,9%
Madrid	23.	25,9%	45,4	2,7%	3,4%	10,2%	0,5%	8,5%
Istanbul	24.	26,2%	44,5	4,3%	1,3%	10,4%	0,8%	9,5%
Rome Fiumicino	25.	26,7%	44,0	4,6%	3,2%	8,9%	0,9%	9,2%
Athens	26.	26,9%	43,9	7,8%	2,7%	5,5%	0,3%	10,7%
London Heathrow	27.	27,9%	33,7	5,9%	1,9%	9,3%	0,7%	10,6%

** Ranking out of 27 European airports.*

Source: AEA (2006)



Source: AEA (2006), AEA (2005), AEA (2004)

Figure 5-11: Comparison of AEA punctuality values 2003 - 2005

5.3 Analysis of airport capacity in Europe

The analysis of the airport capacity can be undertaken using the indicator of the evolution of delayed flight s over total operations combined with the evolution of the average delay per flight through time. The increase of the percentage of delayed flights with the increase of total operations and the increase of average delay times can be direct signs of a congested airport facility with capacity shortages.

The following analysis is performed using general Eurostat data and specific AEA data on delays. Table 5-9 provides an overview of the evolution of total traffic (expressed percentage variation of the total passengers transported), percentage of flights "officially delayed" and average delay per ("officially delayed") flight in the Top10 European airports as ranked according to 2005 figures. There are three trends that can be highlighted:

- There is an important increase in the total transported passengers by all airports (Paris Orly the lowest with 8.1%, along with Paris CdG with 11.4%; Barcelona and Madrid the largest changes, with 68.9% and 63.3% respectively);
- There in a general reduction in the average annual delay minutes per "officially delayed flight" in all airports except for Amsterdam (increase of 11.70%), Paris Orly (10.26%) and Rome (1.62%);
- In terms of the percentage of delayed flights over total flights, all but 2 airports had very significant reductions, with Madrid and Barcelona having the largest reductions in delayed flights (47.7% and 47.2%).

Table 5-9 – Evolution of delay variables across the Top10 European airports

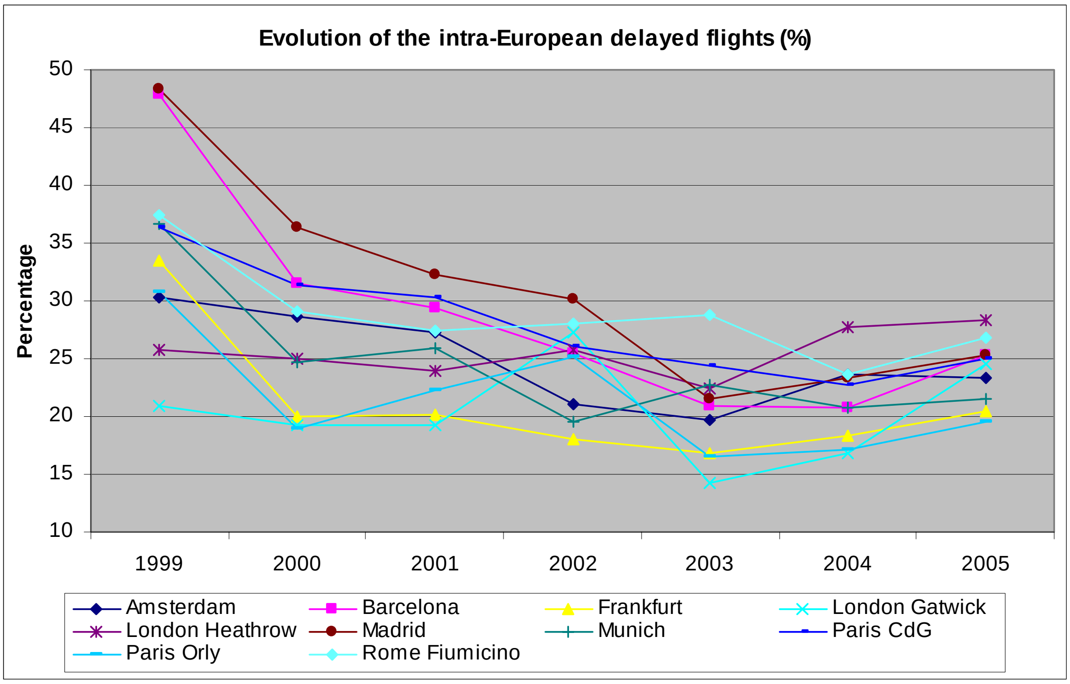
	1999-2005 % change in total passengers	1999-2005 % change in average delay	1999-2005 % change in delayed flights
Amsterdam	21	11,7	-23,1
Barcelona	68,9	-11,74	-47,2
Frankfurt	14,7	-4,64	-38,8
London Gatwick	18,3	-16,09	17,2
London Heathrow	23,4	-15,96	10,5
Madrid	63,3	-6,2	-47,7
Munich	36,6	-5,91	-41,4
Paris CdG	11,4 (*)	-4,63	-31,3
Paris Orly	8,1 (*)	10,26	-36,4
Rome Fiumicino	19,2 (*)	1,62	-28,3

(*) Data available only from 2001 on

Source: own elaboration from Eurostat and AEA data

The only Top10 airports that cannot reduce the number of delayed flights during the period are Heathrow and Gatwick, the largest London airports. The increase in passengers (and operations) during the period meant more delays. In fact, the London airports are the ones with the best evolution in terms of reduction of delay minutes per flight in average terms and, at the same time, the worst evolution in terms of percentage of delayed flights. This means that, although capacity in both airports is not available and both can be considered as congested, operations are handled in a quite efficient manner. The rest of the Top10 can be considered as not congested, as the infrastructure has been able to cope adequately with the continuous increases in operations.

The evolution of the delayed flights is presented in Figure 5-12 the reduction of the percentage of delayed flights has been largely reduced during the period[6]. After 6 years the percentage of delayed flights seems to be stable for the Top10 airport in an interval between 20% and 30%. The best performing airports are Frankfurt and Paris Orly, and the worst performing ones are Heathrow and Rome.



Source: own elaboration from AEA data

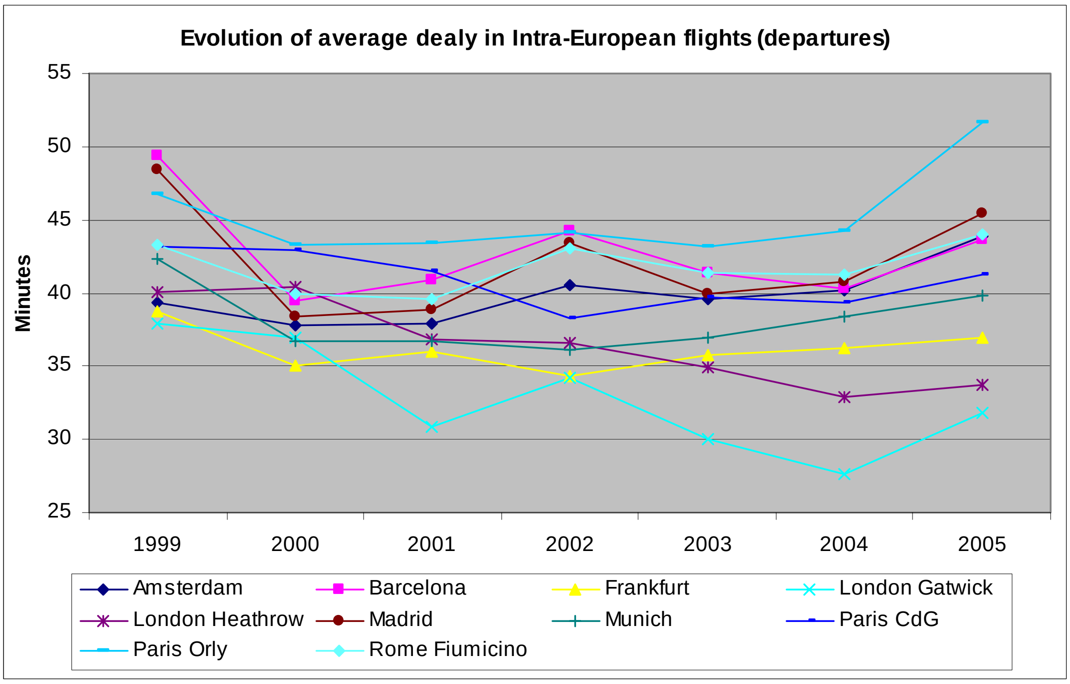
Figure 5-12 – Percentage of delayed intra-European flights (delays over 15 minutes)

Figure 5-13 presents the evolution of the annual average delay per flight. After the 1999 restrictions, the data grouped within an interval approximately between 35 and 45 minutes. However, most airports have worsened the average delay after 2004. This result from the Top10 is perfectly compatible with the results taken from the CODA diagrams analysis, that presented a slight increase in the delay in the main 10 regional European flows.

In the following we present the detailed analysis on capacity and congestion for several European airports. The airports chosen for the analysis, along with the reason for the selection, are the following: London Heathrow, London Gatwick, Paris Orly, Paris CdG, Frankfurt and

[6] It must be remembered that 1999 figures must area marked by the restrictions to air traffic derived from the Kosovo conflict.

Madrid. The airports were chosen according to several variables, such as their weight in the European transport system and the performance concerning delayed flights evolution.



Source: own elaboration from AEA data

Figure 5-13 – Average delay per delayed flight of intra-European flights

5.3.1 London Heathrow

The analysis on capacity for the selected airport will combine the use of Eurostat data and AEA data. The first result, presented for Heathrow, is the comparison between the real growth of total passengers transported and the increase in the percentage of flights "officially delayed". In order to provide a better ground for comparison, both series were normalised to an index with value 100 in 2001[7].

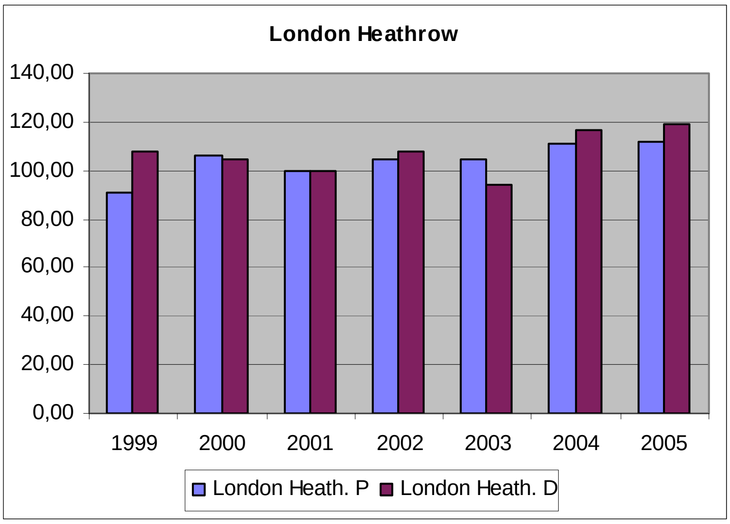
Figure 5-14 presents a parallel growth of the passenger and delay indexes during the period. This means that more operations provoked more delays in Heathrow and there was not a dissociation between the evolution of flights ("P" bars) and percentage of delays ("D" bars). This is a clear indicator that the airport is operating near its total capacity, and thus can be classified as congested. Figure 5-15 shows how the delay sources have maintained their weight in the creation of delays during the period. This is another sign of a congested infrastructure: although late arrival has an important weight in total delays, some airport own sources have a negative evolution, as pre-flight procedures and A&ATC, that after a short period of reduction rises again after 2003. Compared with the other Top10 EU airports (see

[7] The values were normalised in 2001 because this is the first year with availability of passenger data for the Paris airports.

Figure 5-12), Heathrow has the first place in percentage of delayed flights over total intra-European flights (around 28%).

In order to reduce the present situation of congestion Heathrow airport is undertaking an important investment in the new Terminal 5 (T5)[8]. It is due to open on the 30th of March 2008, amounting for £4.2 billion investment, will increase Heathrow's capacity for around 30 million passengers annually and provide new terminal and airfield capacity. Airways will transfer its entire operation to T5, leaving spare capacity in Terminals 1 and 4.

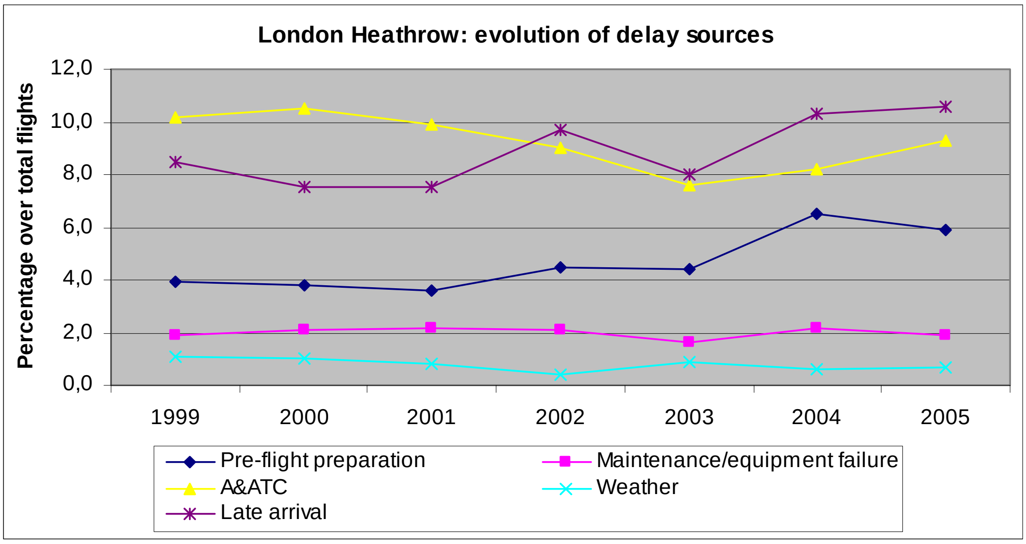
After the completion of T5, the BAA will initiate the renewal of Terminal 1 and 2. The projects are not presented as capacity building, but as the modernisation of the oldest terminals of the airport. The works are scheduled to be finished by 2012.



Source: own elaboration from Eurostat and AEA data

Figure 5-14 – London Heathrow: comparison between passenger and percentage of delayed flights growth

8 BAA explicitly recognises through the Heathrow web page the congestion situation of the airport.



Source: own elaboration from AEA data

Figure 5-15 – London Heathrow: evolution of the delay sources

5.3.2 London Gatwick

The evolution of Gatwick is very similar to Heathrow: passenger and delays growth follow parallel path, showing a high correlation between the increase in operations and the increase in the percentage of delayed flights (see Figure 5-16). The delay sources increase their participation in the percentage of delayed flights, with A&ATC and pre-flight preparations growing around 2% each year since 2003 (see Figure 5-17). Figure 5-12 presents the evolution of Gatwick within the Top10 airports, that passed from a value under 15% of delayed flight over total intra-European departures in 2003 to almost 25% in 2005. This steep increase (10% in two years) was not accompanied by a similar increase of the number of passengers transported. This is, the increase in operations was smaller than the increase in percentage of delays over operation, which can be a sign of a congested infrastructure.

In total, Gatwick can be considered at this moment as a congested airport, operating near its full capacity. It is important to remark that Gatwick is a single runway airport, which limits largely its operational capacity, and this could have contributed to put it between top generators of delays in the departures of intra-European flights. Airline pre-flight operations and A&ATC are the delay sources that have raised the delay rate of Gatwick, as well as the late arrival of aircrafts.

BAA plans for the expansion of Gatwick are subject to the realisation of another Heathrow project, the construction of a new runway. If this project wouldn't be undertaken, BAA would proceed to the construction of the second runway at Gatwick increasing the capacity of the airport up to 45 million passengers per year. The works would be finished by 2019[9].

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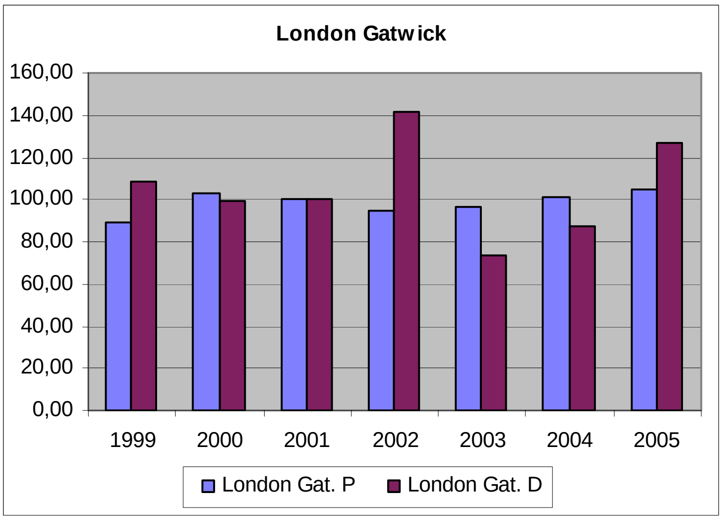
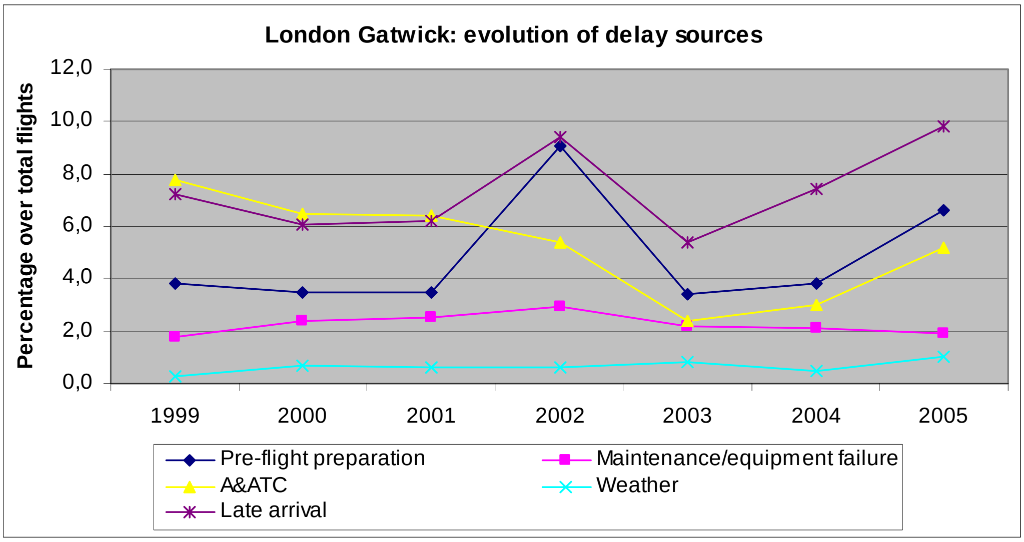
[9] Source: http://www.gatwickairport.com/



Source: own elaboration from Eurostat and AEA data

Figure 5-16 – London Gatwick: comparison between passenger and delayed flights growth



Source: own elaboration from AEA data

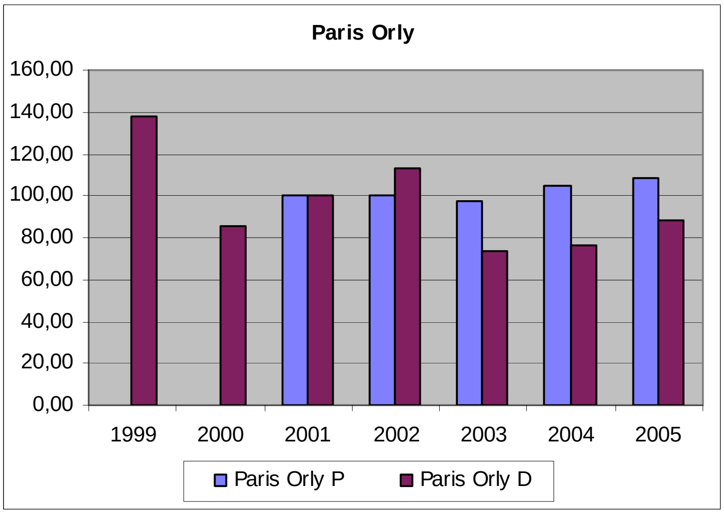
Figure 5-17 – London Gatwick: evolution of the delay sources

5.3.3 Paris Orly

Orly airport presents a very different evolution to that from the London airports: Figure 5-18 presents a dissociation between the growth passengers transported (and subsequently operations) and delays fro 2003 on. Figure 5-19 presents a general reduction of the main delay sources, with a slight increase after 2003, still in average under the figures of the London airports. In general terms, Orly cannot be considered as a congested airport attending to the data presented. Figure 5-12 presents Orly as one of the least congested airports during the period, being in 2005 the airport that generated the lowest proportion of delays over total intra-European departures (less than 20%).

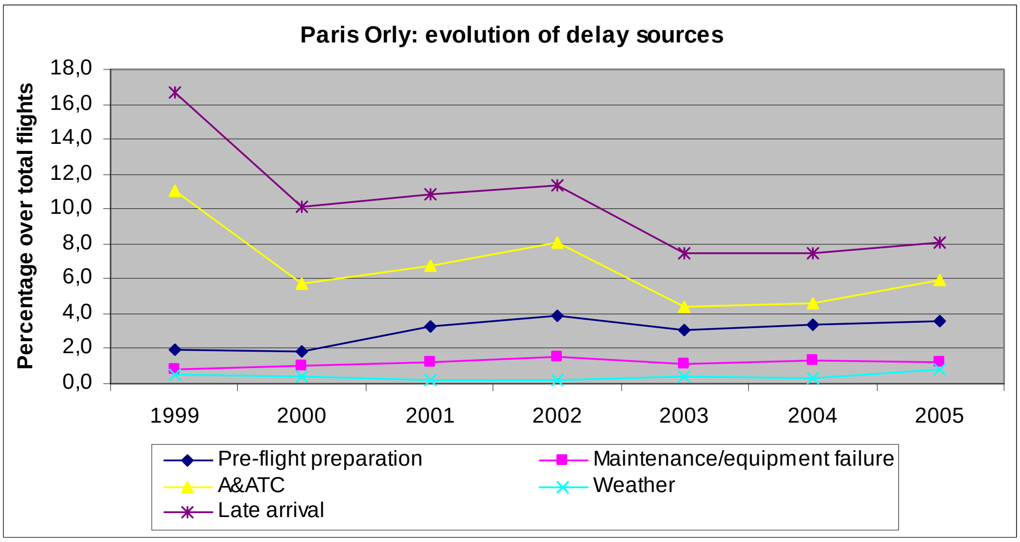
Concerning the importance of the delay sources, late arrival of aircrafts is the one with more weight, although with an average value of 8% which is the average value of the European airports analysed (it could be classified as a "systemic value").

As a resume, it can be said that Orly is one of the less congested airports of the group analysed, according to the available data.



Source: own elaboration from Eurostat and AEA data

Figure 5-18 – Paris Orly: comparison between passenger and delayed flights growth



Source: own elaboration from AEA data

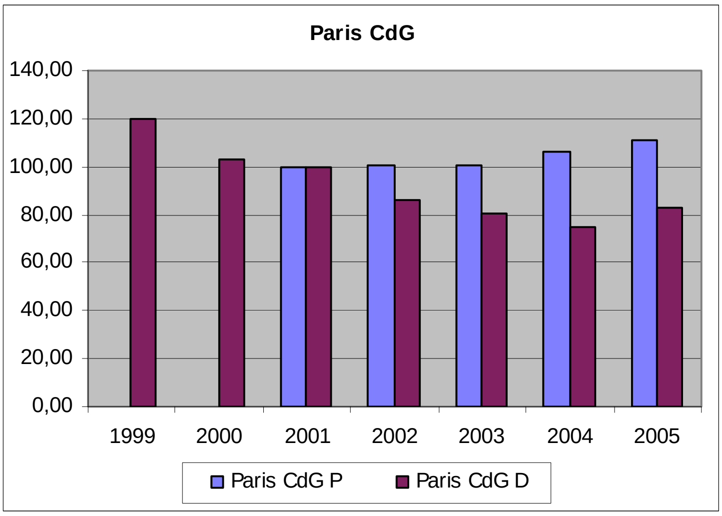
Figure 5-19 – Paris Orly: evolution of the delay sources

5.3.4 Paris CdG

The dissociation between growth of operations and percentage of delayed flights is much clearer in the data from the Charles de Gaulle airport: since 2001, total passengers transported have grown at a significant rate, while delayed flights have decreased quite rapidly, with a slight increase in 2005 (see Figure 5-20). The reduction in the percentage of delayed flights can be observed more clearly in Figure 5-21: the slow decrease of all sources changed in 2005 with an increase of delays due to pre-flight operations.

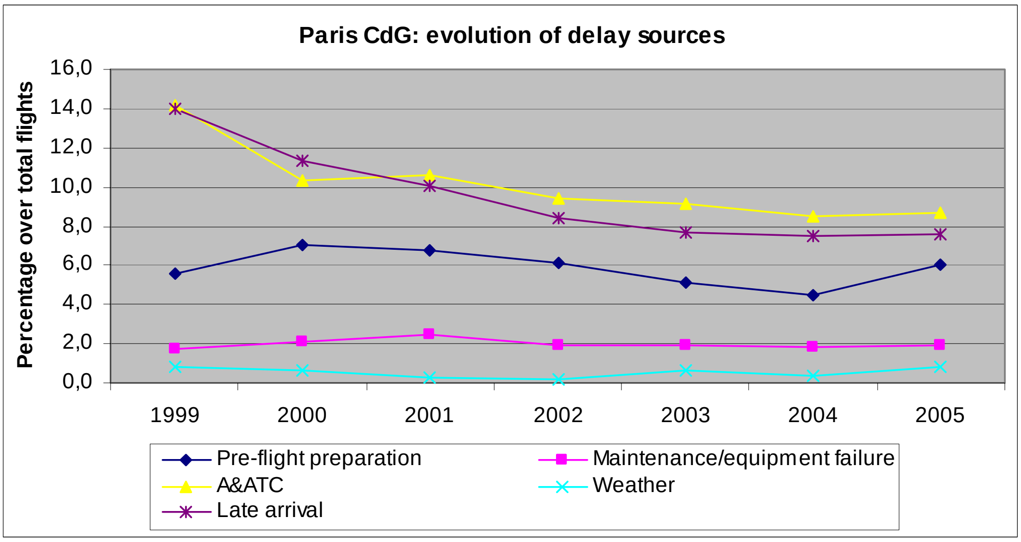
During the 1999-2005 period, Paris Charles de Gaulle was one of the airports with the highest rates of delayed flights over total operations, according to the AEA data (see Figure 5-12). In 2005 the percentage of delayed intra-European flights was of 25%. The most relevant delay source during the period was A&ATC, which implies a certain level of congestion of the airport procedures and air traffic systems. This is not surprising, as Paris Charles de Gaulle has experienced an important growth in recent years and is at this moment the main hub of Air France-KLM. The growth of the Paris Charles de Gaulle began with the construction of two new runways in 1998 and 2000, having reached in 2005 nearly 54 million passengers, taking the second place in the European airport ranking surpassing Frankfurt. This is also reflected in the share of pre-flight procedures delays, which was in average 6% during the period, on of the highest of the airports analysed.

It can be said that the Paris Charles de Gaulle airport is not congested in general terms, despite the high percentage of delays that presents. The high level of A&ATC delays can be due to its hub character, being the capacity built up undertaken by the end of the 90s the best insurance that the airport has at this moment against congestion.



Source: own elaboration from Eurostat and AEA data

Figure 5-20 – Paris Charles de Gaulle: comparison between passenger and delayed flights growth



Source: own elaboration from AEA data

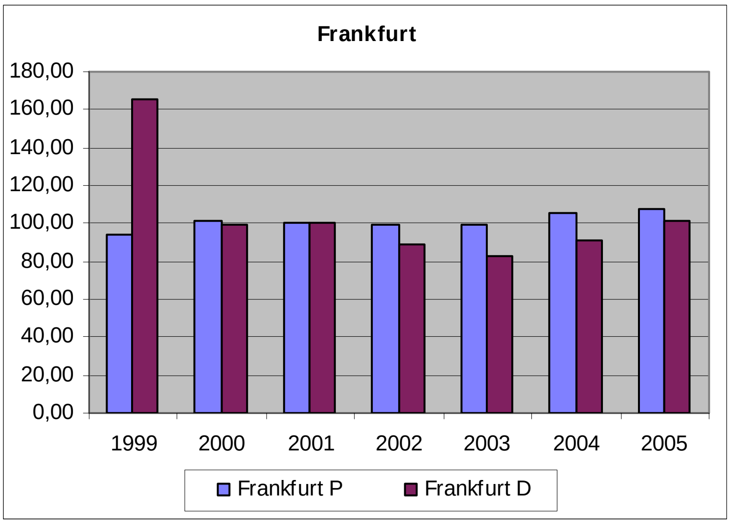
Figure 5-21 – Paris Charles de Gaulle: evolution of the delay sources

5.3.5 Frankfurt

Frankfurt is the third largest European hub and has at the same time the best performance in terms of percentage of delayed flights (see Figure 5-12) with around 20% in 2005. Figure 5-23 presents a panorama of low contribution of all delay sources to the creation of delays: A&ATC is under 6% after 2002 and the other causes (except the 8% "systemic value" of late arrivals) are around 2%.

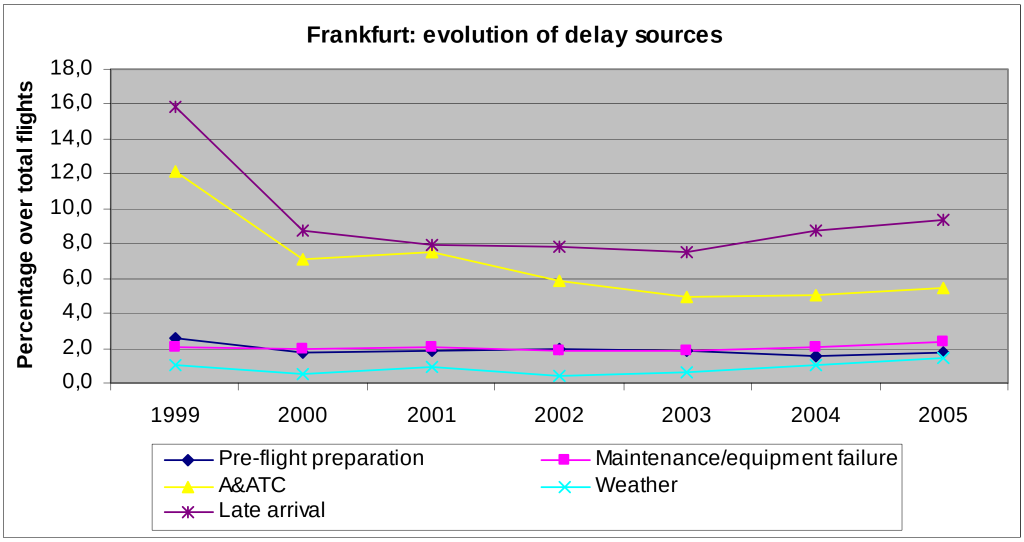
Figure 5-24 presents certain degree of dissociation between the growth of total passengers transported and percentage of delays generated. The trend started to change in 2004, when the percentage of delayed operations began to be higher than the growth of passengers transported. In general terms, Frankfurt is not a congested airport. Despite its condition of European and international hub, the low percentage of delayed operations due to A&ATC (possibly due to efficient airport and air traffic management) and the large capacity available contribute to that.

Within the system of German airports large capacity expansion programmes are planned for the future. Until 2009 Frankfurt will construct a new runway which will, however, be accompanied by a ban of night flights. Also Munich is opting for a third runway and Berlin will replace its three airports by a single hub airport. The new Berlin-Brandenburg International Airport (BBI) is scheduled for 2010.



Source: own elaboration from Eurostat and AEA data

Figure 5-22 – Frankfurt: comparison between passenger and delayed flights growth



Source: own elaboration from AEA data

Figure 5-23 – Frankfurt: evolution of the delay sources

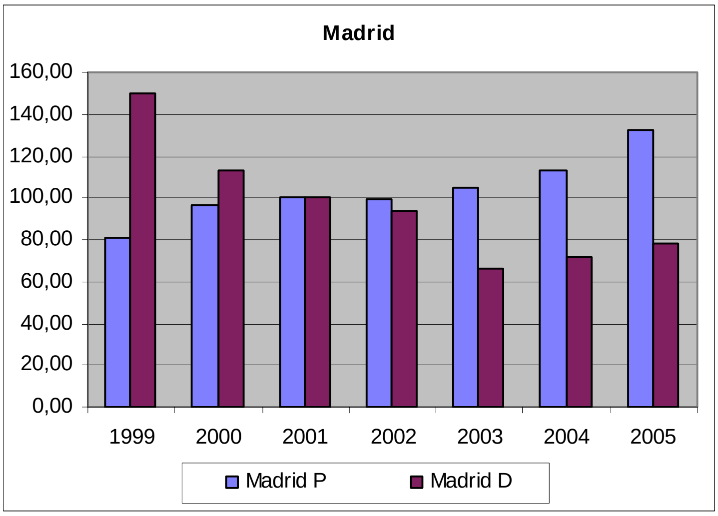
5.3.6 Madrid

From all the airports analysed in detail, Madrid is the one that presents a clearer dissociation between passenger transported and percentage of delays (see Figure 5-24): since 1999, the growth rate of the passengers transported ahs been of 50% and the reduction in percentage of delayed operation has been of 70%. On one hand, the total passengers transported have grown from 27 to 45 millions. On the other, the percentage of delays has fallen from 48% to 25%. Still, Madrid can be counted amongst the worst performers in terms of percentage of delayed flights, as presented in Figure 5-12.

Concerning the evolution of the delay sources (see Figure 5-25), the most important source is A&ATC with similar numbers to those of Paris Charles de Gaulle but higher than most of the airports. The late arrival of incoming aircrafts has the habitual average 8% "systemic value".

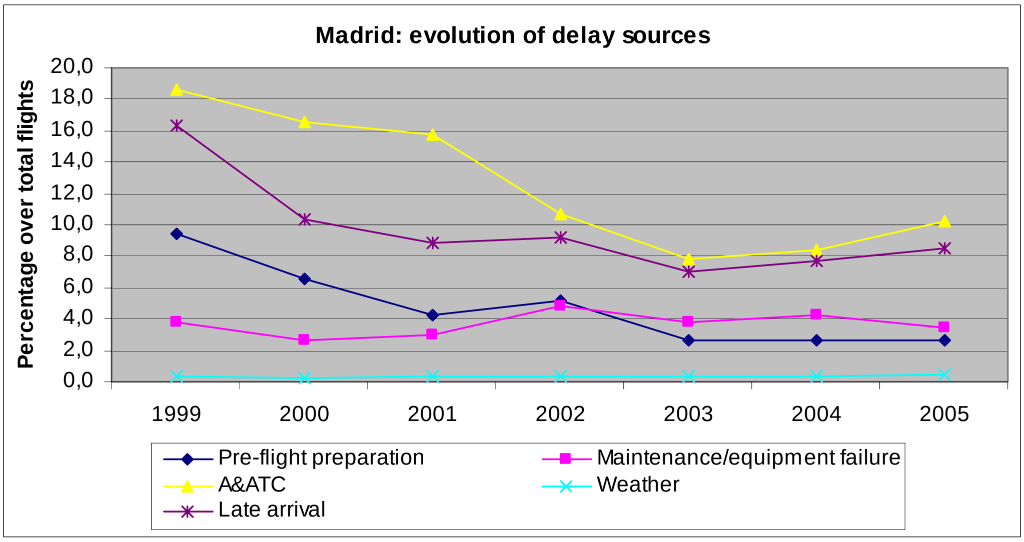
The dissociation between passenger transported and percentage of delays has been achieved in Madrid with continuous increases in capacity. The last development was the entry into service of the new Terminal 4 (T4) last February. T4 has a maximum capacity for handling 35 million passengers per year, more than 10.000 during peak hours. Iberia has centralised at T4 its operation, making available capacity for other companies in Terminals 1, 2 and 3. In total, Madrid airport has a maximum capacity over 75 million annual passengers.

With these investments and numbers associated, Madrid airport is clearly far from congestion with a large quantity of spare capacity.



Source: own elaboration from Eurostat and AEA data

Figure 5-24 – Madrid: comparison between passenger and delayed flights growth



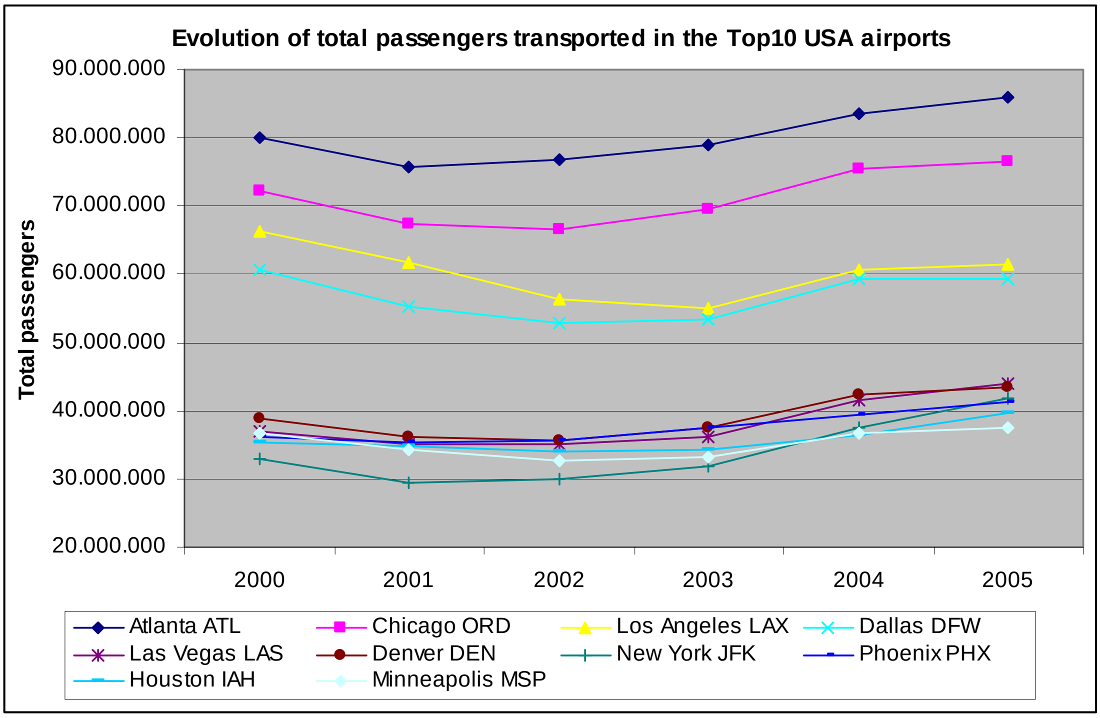
Source: own elaboration from AEA data

Figure 5-25 – Madrid: evolution of the delay sources

5.4 General situation of delays in the USA

5.4.1 Total delays to air tranasport

The USA air transport sector is characterised by a general reduction in the numbers of passengers transported and, subsequently, total operations, since 2001. The 9/11 terrorist attacks had a devastation effect on the USA transport industry from which it is still recovering. Figure 5-26 presents the evolution of total passengers transported by the Top10 USA airports between 2000 and 2005. All airports suffered a significant reduction in passengers transported during 2001, being still some of them under 2001 traffic levels. For instance Los Angeles, Dallas and Minneapolis airports are still under the 2001. On the other hand, the rest of the Top10 has already surpassed the 2000 values barrier, although none of them achieved this until 2004.



Source: own elaboration from ACI data

Figure 5-26 – Evolution of the total passengers transported by the Top10 USA airports

The total volume of the industry, according to BTS figures, accounts for more than 652 million passengers boarded through the USA airports. The figure can be corrected to calculate the total passengers transported taking into account that per boarded passenger there is, at least, 1 passenger in transit. In fact, the average percentage of the Top10 USA airports is of 46% boarded passengers and 54% transit passengers[10]. This means that the total figure of passengers transported by the USA airport system might well exceed 1.400 million passengers. Table 5-10 presents the evolution of the total passengers boarded in the whole USA airport system between 1994 and 2004. In terms of freight transport, the industry suffered as well from the 9/11 attacks: total transported tonnes fell from 1993 (4.5 millions tonnes) to 2002 (3.8 millions tonnes) by 16%.

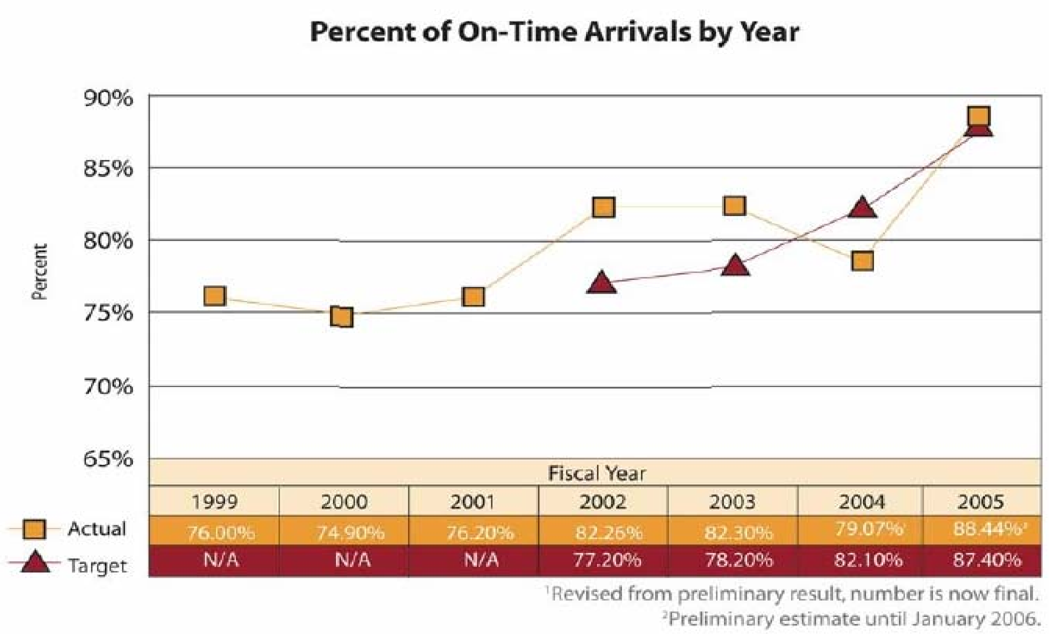
Table 5-10 – Evolution of total passengers boarded in the USA airports

	1994	2003	2004	% change 1994-2003	% change 2003-2004
All USA airports	501.196.972	594.301.990	652.712.322	19%	10%

Source: own elaboration from BTS data

10 Source: own comparison and calculation of average values between ACI passengers transported data and BTS boarded passenger data for the Top10 USA major airports.

As presented above, the scenario of the USA air transport industry is one of strong recession, with reductions in demand levels (both passengers and freight) and restrictions to air transport operations. A first approach to delays in the USA air transport industry can be taken from the Federal Aviation Administration. The FAA provides in its annual reports the performance of the air transport system in terms of punctuality. The overall measure used for comparability terms is the percentage of on-time arrivals per year. Based in this number and in the situation of the industry, the FAA sets targets for the annual performance indicators. Figure 5-27 presents the percentage of on-time arrivals between 1999 and 2005. 2002 was the first year of implementation of the "target policy" and since then punctuality in arrivals has always been over the target, except for 2004. The FAA indicator is quite vague, but gives an interesting annual snapshot of the overall performance of the industry. Between 2004 and 2005 there was the largest reduction in the percentage of delayed arrivals in the USA airport system since 1999.



Source: FAA (2006)

Figure 5-27: Development of US air traffic delays (all causes)

Table 5-11 presents the values of the percentage of delayed flights for the Top5 airports. In general, it can be said that the values are quite moderate and the evolution is positive, with only one airport (Atlanta, the biggest world airport) increasing the rate of delays.

Table 5-11 – USA Top5 airports: percentage of delayed flight

	2004	2005
Atlanta	23,2%	24,5%
Chicago	26,1%	22,2%
Los Angeles	17,0%	18,7%
Dallas	16,1%	16,9%
Las Vegas	21,4%	21,3%

Source: own elaboration from BTS data (DOT 2006)

Similar to the AEA consumer reports (AEA 2006), the US Department for Transportation (DOT) presents monthly consumer reports on the quality standards of US airlines related to punctuality, cancelled flights and lost baggage. An example table for the year 2005 taken out of DOT (2006) is presented by Table 5-12. More detailed information by airport and carrier is available by the other monthly issues of the DOT consumer reports (since 1998) and via an online database on the BTS website (since 2004 only).

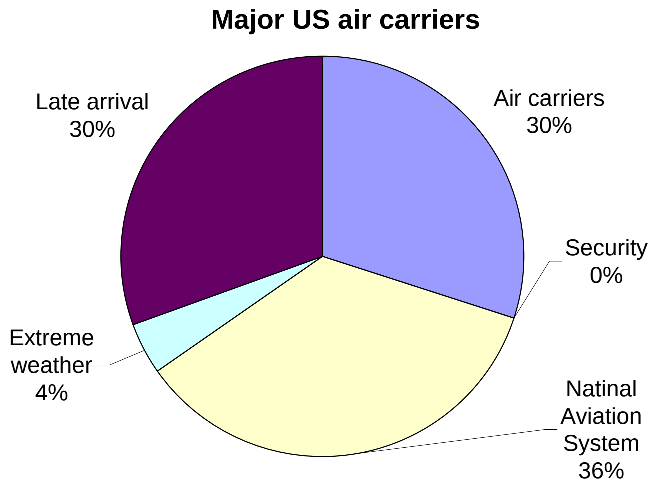
Table 5-12: Overall performance of reported flight operations arriving on time and carrier rank, by month, quarter, and database to date

CARRIER	1st QUARTER 01 - 03 2005		2nd QUARTER 04 – 06 2005		3rd QUARTER 07 – 09 2005		4th QUARTER 10 - 12 2005		OCT - 05		NOV - 05		DEC - 05		12 MONTHS ENDING DEC 2005		DATABASE T0 DATE SEP 1987- DEC 2005	
	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
AIRTRAN	68.8	17	75.3	17	68.4	19	72.6	19	74.6	20	77.9	14	65.7	17	71.3	17	(--)	(--)
ALASKA	72.9	15	61.6	19	70.2	18	74.4	15	80.5	13	75.4	18	67.3	16	69.7	19	75.9	9
AMERICA WEST	76.7	6	83.8	6	81.6	5	82.6	2	84.1	5	85.2	3	78.5	3	81.2	4	78.7	5
AMERICAN	76.2	7	80.7	9	73.7	13	76.9	12	82.1	10	79.9	10	68.9	11	76.9	10	79	3
AMERICAN EAGLE	74.2	14	79.3	12	75.1	11	76.2	13	82.7	7	77.7	15	68.2	14	76.2	12	75.5	10
ATA	77.5	4	86.5	2	82.5	4	79.3	8	82.5	8	81.7	7	72.2	8	81.3	3	(--)	(--)
ATLANTIC SOUTHEAST	68.2	18	75	18	66.8	20	73.4	18	77.4	17	76.7	17	65.4	19	70.9	18	(--)	(--)
COMAIR	74.8	12	85	4	81.1	6	79.5	7	84.9	4	79.2	12	72.6	6	80.1	6	(--)	(--)
CONTINENTAL	75.8	9	81.1	8	74.7	12	76	14	78.1	16	79.3	11	71	9	76.9	9	78.8	4
DELTA	75.2	11	80.5	10	72.3	15	77.2	11	80.1	14	78.4	13	72.6	7	76.3	11	77.7	7
EXPRESSJET	74.4	13	81.1	7	72	16	74.3	16	76.8	18	77.4	16	69.1	10	75.4	14	(--)	(--)
FRONTIER	(--)	(--)	(--)	(--)	85.7	2	79.7	6	86.2	3	85.3	2	67.9	15	(--)	(--)	(--)	(--)
HAWAIIAN	93	1	95.2	1	96.8	1	95.4	1	96.8	1	95.2	1	94.2	1	95.1	1	(--)	(--)
INDEPENDENCE AIR	77.4	5	77.7	15	76.5	10	81.9	3	82.5	9	84.4	4	78.7	2	78	7	(--)	(--)
JETBLUE	65.8	19	76.2	16	72.7	14	70.8	20	75.1	19	74.6	20	63.7	20	71.4	16	(--)	(--)
NORTHWEST	75.2	10	80.4	11	70.5	17	73.7	17	80.6	12	74.9	19	65.6	18	75	15	79.7	2
SKYWEST	79.3	2	86.3	3	85.3	3	78.8	9	86.3	2	81.3	8	68.6	12	82.5	2	(--)	(--)
SOUTHWEST	78.6	3	84.5	5	79.3	7	80.6	4	80.8	11	84	5	77.2	4	80.7	5	82.3	1
UNITED	75.9	8	78.4	14	78.8	8	77.4	10	83	6	81.2	9	68.2	13	77.6	8	76.3	8
US AIRWAYS	70.2	16	78.5	13	77.1	9	79.7	5	79.8	15	82.7	6	76.5	5	76.2	13	78.5	6
Total	75.3		80.8		76.1		77.5		81.3		80.0		71.0		77.4		78.7	

Source: DOT (2006)

5.4.2 Aviation delays by cause

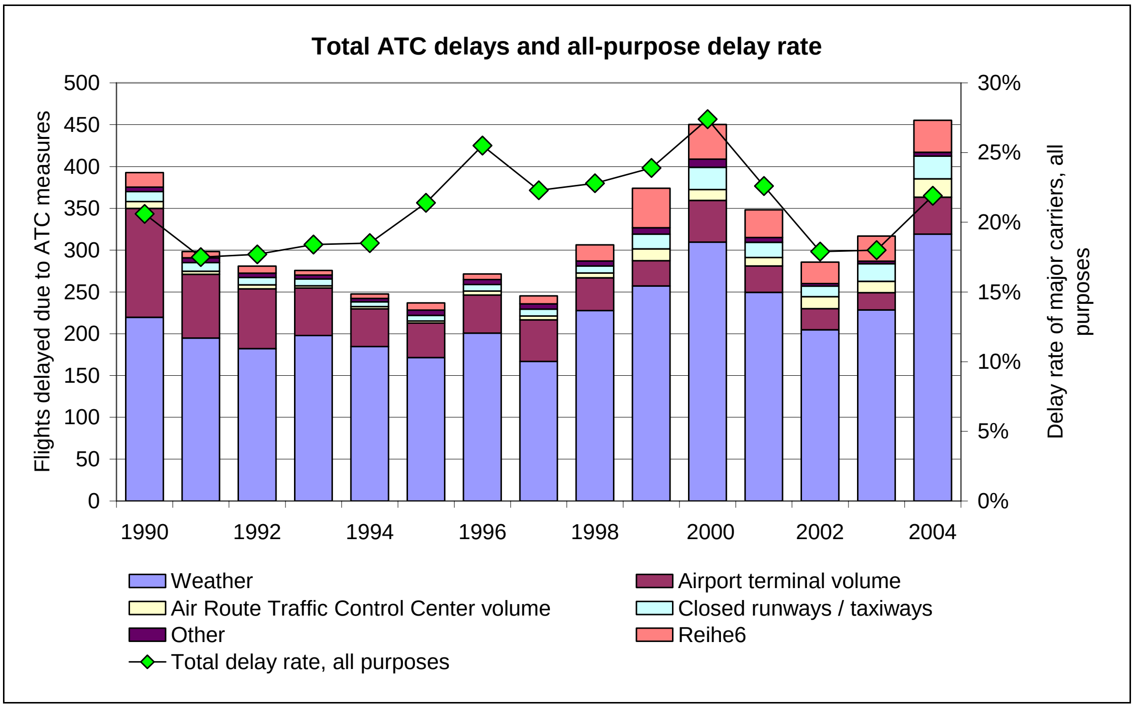
The total distribution of delays by main causes in 2005 for the main US air carriers according to DOT (2006) are summarised in Figure 5-28. The figures appear very similar to those for AEA member airlines in Europe (Figure 5-6)



Source: Data from DOT (2006)

Figure 5-28: Distribution of delay causes for major US airlines 2005

FAA reports on pure air traffic management delays. Their development by cause in relation to overall flight punctuality (all causes) of the major US airlines is presented by Figure 5-29.



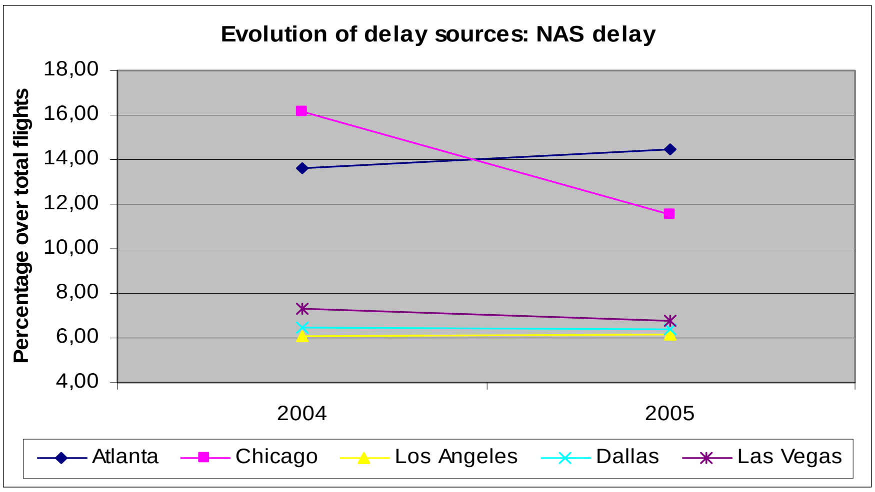
Source: Data from BTS (2006), Table 1-60 and 1-61

Figure 5-29: Comparison of ATC-caused departure and en-route delays to overall delay rates in the US, 1990 - 2004

Total delays reported by Figure 5-29 only relates to those delays caused by air traffic control after pushback of the aircraft. Thus, ATC-caused pre-flight regulations and non-ATC-related delays are not covered. According to this narrow analysis, weather conditions, probably including extreme as well as non-extreme conditions, are predominant to ATC regulation measures. The figure shows that, apart from a peak in total delays around 1995 when ATC delays have ranged at a minimum, ATC-caused and total delays follow a more or less parallel development. This observation indicates the importance of airspace capacity for the performance of the entire aviation sector.

Further, the BTS provides a more disaggregated measure of punctuality in a database (BTS 2006b) that contains all delays by all causes occurred in the USA airports classified by cause for flights covering non-stop flights between two points within the USA territory. The delay sources classification is the one presented at the beginning of the Report. The delay sources are: air carrier, security, NAS, late arrival and extreme weather. The only drawback of the database is its short availability: only in the second semester of 2003 the BTS started to record all delays using the above referred classification, making the comparison per airport limited[11]. The BTS data are very disaggregated, and are gathered from reports delivered by 19 main USA based airlines. The following pages present the evolution of the delay source accounted by the BTS system.

The most important delay source in the USA airport system is the National Aviation System. For the Top5 airports, values for 2005 NAS delays vary within an interval between 6% and 15%. This is a 9% interval, almost double than the equivalent European source, A&ATC, which varies between 5% and 10%. In Figure 5-30 it is important to remark the high dispersion of the values: three airports (Las Vegas, Dallas and Los Angeles) have "low values" grouped around an average value of 7%. However, the two main USA hubs (Atlanta and Chicago) have much higher value, almost double. This can be a clue for a higher congestion. In terms of data trend, the short time series doesn't provide a good perspective, although all airports but one seem to follow a more or less steep descending path.

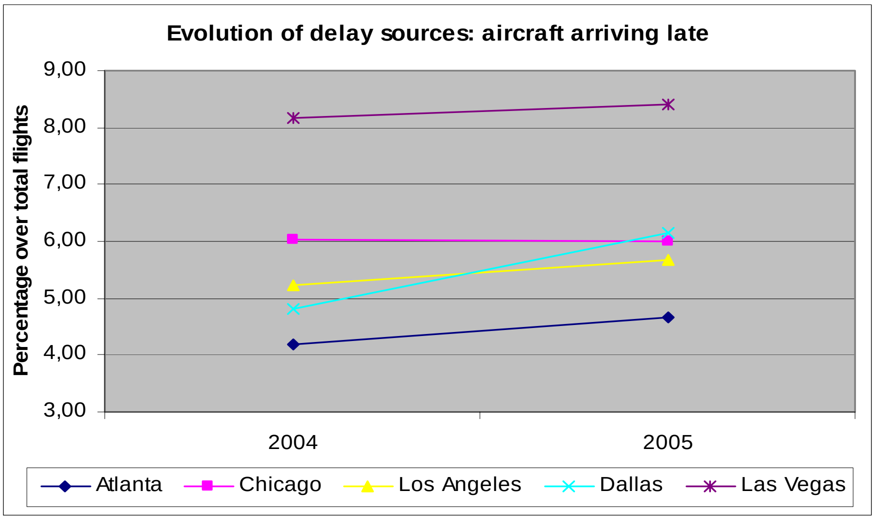


Source: own elaboration from BTS data

Figure 5-30 – Delay sources evolution at top-5 US airports: National Aviation System

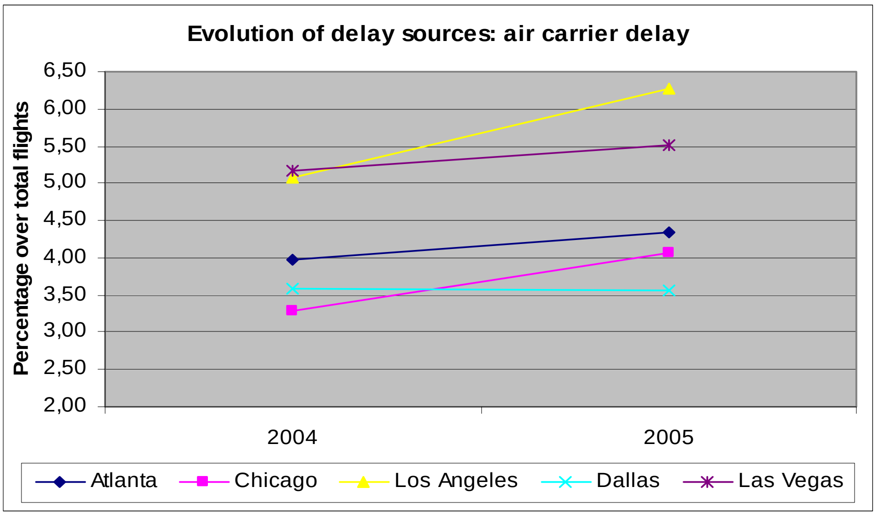
11 The DOT issued the final rule on reporting flight delay causes on the 25th of November 2002.

After NAS, aircraft arriving late and air carrier are the most significant sources of delay. Late arrival of aircraft varies in 2004 and 2005 in an interval within 4% and 9%, with quite clear trend for rising in all airports (see Figure 5-31). Compared with its European equivalent, in average the USA figure is lower, and the interval has a similar width, around 4%. On the other hand, air carrier delays (see Figure 5-32) have a lower value than in Europe, as the equivalent would be the sum of pre-flight operations and maintenance/equipment failure. The USA category varies between 3% and 7%, while the combination of the two airline categories of the EU system accounts for an interval approximately between 2% and 9%. The larger dispersion of the values in the European case is largely due to the sum of the 2 delay sources.



Source: own elaboration from BTS data

Figure 5-31 – Delay sources evolution at top-5 US airports: aircraft arriving late

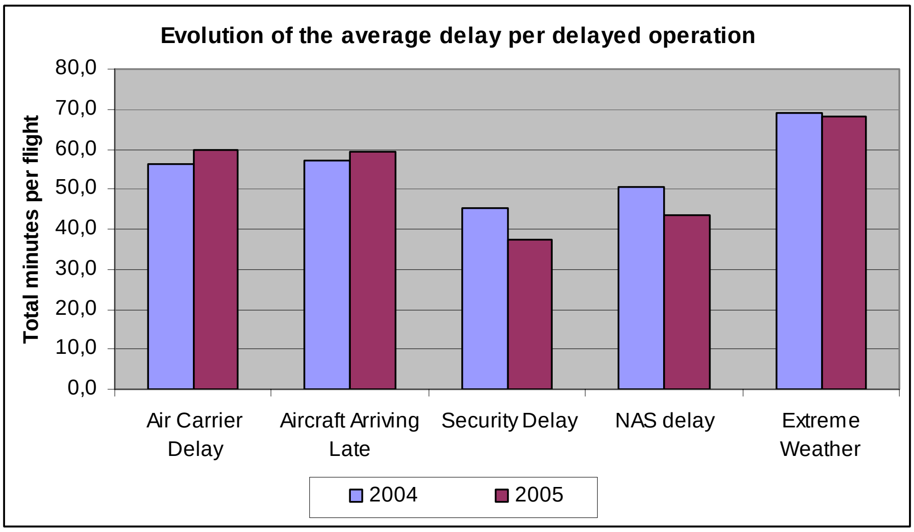


Source: own elaboration from BTS data

Figure 5-32 – Delay sources evolution at top-5 US airports: air carrier delay

Finally, the other 2 delay sources in the USA system can be considered as residual. Extreme weather delays accounts for an average value in 2005 under 0.7% of all delays, and security has an even smaller value, around 0.04% of all delayed flights.

The evolution of the delay time is as well limited by the availability of BTS data. Figure 5-33 provides the comparison of the average annual delay (minutes) per delay source for 2004 and 2005, only for the "officially delayed flights". Security and NAS are the two delay sources with appositive evolution, reducing their values quite significantly. Given its very low weight in the total delays, security has almost no impact in the system, but NAS delays account in some airports for a large percentage of the total delays (for instance, in Atlanta, more than 14% in 2005).



Source: own elaboration from BTS data

Figure 5-33 – Evolution of the total delay per "officially delayed" flight (over 15 minutes)

5.5 Analysis of airport capacity in the USA

The present context of the USA air transport industry is one of slow recovery from negative effects of the 9/11 terrorists attacks. Some airports are still under the traffic levels recorded in 2000. The panorama on congestion, as presented previously, is a quite mild one, with FAA punctuality indicators high for the joint system and some important delay sources (NAS) reducing the average delay per delayed flight.

Table 5-13 presents an overview of the evolution of several variables related with delays and capacity for the Top5 USA airports. It provides an overview of the evolution of total traffic (expressed in percentage variation of the total passengers transported), percentage of flights "officially delayed" and average delay per ("officially delayed") flight. Some results that can be highlighted:

- In general the increase of traffic is still moderate, even having a negative growth by Dallas. Compared with the European airports, this annual growth rate is very small, with some airports as Madrid and Barcelona growing 10% per year since 1999;
- The change in the percentage of delayed flights is very variable, and includes a 15% reduction (Chicago) with important increases (such as Los Angeles, with 9.6%).

Table 5-13 – Evolution of delay variables across the Top5 USA airports

	2004-2005 % change in total passengers	2004-2005 % change in delayed flights
Atlanta	2,8	5,8
Chicago	1,3	-15,0
Los Angeles	1,3	9,6
Dallas	-0,4	5,5
Las Vegas	6,1	-0,3

Source: own elaboration from BTS data

A first global approach to capacity and congestion in the USA airports, given the results presented up to now, is that the sector is far from congestion point. Some airport present characteristics of operating already with a certain level of congestion, but we must remember that most of the airport have not yet recovered from the 2001 crisis. Moreover, the recent increases in oil prices seem to have slow down the recovery that started for most of the main hubs in 2003 (see Figure 5-26). The Airport Council International (ACI) North America referred on its document "State of the Industry 2005" that airports halted their capacity investments after September 11 due to the decline in traffics. However, during 2005 was the first year since 2005 that the first signs of congestion have emerged in several airports, and the industry is undertaking or is planning new investments to prevent further congestion problems.

Figure 5-34 provides a schematic vision of the main commercial USA airports that have some kind of congestion due to terminal airspace or problems. The classification of the problems has an engineering approach but the problems by themselves constitute barriers for development and variables influencing congestion sources such as NAS and air carrier delay[12]. Red represents congestion problems with the departures, and blue congestion problems with arrivals. Table 5-14 resumes the situation of the Top5 USA airports. It is important to remark that the information presented corresponds to 2001. Nevertheless, this information is fully valid, as due to the 9/11 and the subsequent crisis of the industry, traffic levels in most airports are only now reaching dangerous levels concerning congestion. The description of the congestion problems is as follows:

- **Airspace limitation**: concerning limitations to air traffic and bottlenecks in operations from the "air side", this is, approaching and taking-off operations, in the air waiting times, etc;
- **Airport limitation**: concerning infrastructure limitations to operations (runway limits, gate operation, etc), but also organisational and coordination issues that hamper efficient land operations;

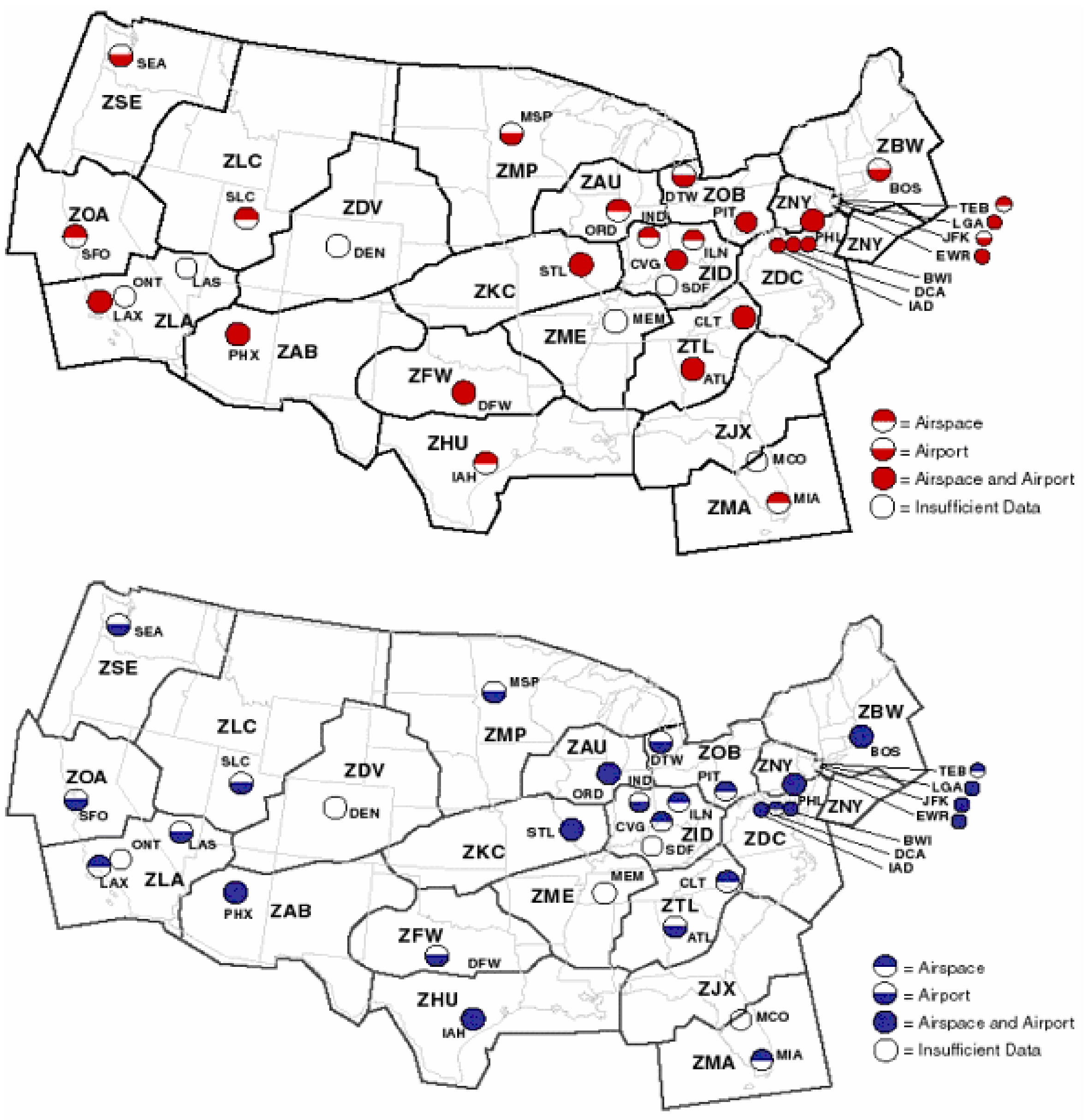
[12] This is, limiting the correct development of airport operations and the optimisation of capacity.

Table 5-14 – USA Top5 status concerning departure/arrival congestion problems

	Departures		Arrivals	
	Airspace limitations	Airport limitations	Airspace limitations	Airport limitations
Atlanta	Yes	Yes	No	Yes
Chicago	Yes	No	Yes	Yes
Los Angeles	Yes	Yes	Yes	No
Dallas	Yes	Yes	No	Yes
Las Vegas	No	No	No	Yes

Source: own elaboration from MITRE Corporation (2001) data

From Table 5-14 we can derive per airport the main potential variables influencing congestion and pressing on the delays sources, both from the air and land side of the operations. For instance, Las Vegas airport presents few barriers for expansion of operations and, thus, fewer potential for congestion in the short term given its present maximum capacity. On the other hand, Atlanta and Dallas are 2 airports with limitation in the land side of the operations. This means than the infrastructure has a high potential for congestion and generation of delays.



Source: MITRE Corporation (2001)

Figure 5-34 – USA airports with departure/arrival congestion problems: red, departures; blue, arrivals

The FAA sets annually a series of targets for the airport industry, including several indicators on capacity goals. The overall objective of the FAA is to provide sufficient capacity to satisfy the expected rise in demand and the return of the USA industry to growth rates pre 9/11. The FAA activities are not focused in increasing capacity through investment, but to promote efficient use of capacity in place. This includes the accommodation of more traffic through improved routing, enhancement of operations in airports, etc. Table 5-15 presents the 2005 goals and the actual results achieved. All goals marked for capacity availability and punctuality were achieved in 2005.

Table 5-15 – Capacity goals and performance set by the FAA for the USA airports

FY 2005 CAPACITY PERFORMANCE MEASURES AND RESULTS			
Performance Measure	FY 2005 Target	FY 2005 Results	Status
Average Daily Airport Capacity (35 OEP airports): Achieve an average daily airport capacity of 104,338 arrivals and departures per day by 2009 at the 35 Operational Evolution Plan (OEP) airports.	99,892	101,463[1]	●
Average Daily Airport Capacity (eight metropolitan areas): Achieve an average daily airport capacity for the eight major metropolitan areas of 44,428 arrivals and departures per day by 2009.	43,080	44,324[1]	●
Annual Service Volume: Open as many as seven new runways, increasing the annual service volume (ASV) of the 35 OEP airports by at least 1% annually, measured as a 5-year moving average, through 2009.	1.00%	1.01%	●
Adjusted Operational Availability: Sustain adjusted operational availability at 99% for the reportable facilities that support the 35 OEP airports.	99.00%	99.76%[1]	●
NAS On-Time Arrivals: Through FY 2009, achieve an 88.4% on-time arrival rate for all flights arriving at the 35 OEP airports. Arrivals are considered on time if they are less than 15 minutes late due to NAS-related delays.	87.40%	88.44%[1]	●
Noise Exposure: Reduce the number of people exposed to significant noise by 1% per year through FY 2009, as measured by a 3-year moving average, from the 3-year average for calendar years 2000–2002.	–3.00%	–27.00%[2]	●
Aviation Fuel Efficiency: Improve aviation fuel efficiency per revenue plan-mile by 1% per year through 2009, as measured by a 3-year moving average, from the 3-year average for calendar years 2000–2002.	–2.00%	–5.84%[2]	●
Oceanic En-route Change Requests: Increase the number of oceanic en-route altitude change requests that are granted through the end of FY 2009 to 80%.	75.00%	76.24%	●

● **Green:** Goal Achieved ◎ **Red:** Goal Not Achieved

1) Preliminary estimate. Final data will be available by January 2006.

2) Preliminary estimate. Final data will be available in May 2006.

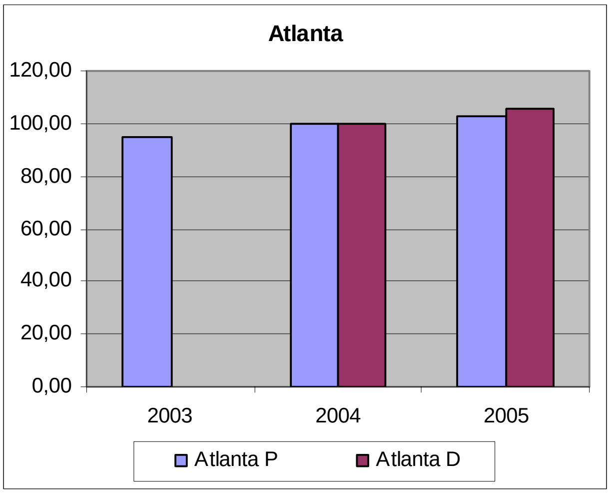
Source: FAA (2006)

5.5.1 Atlanta

Figure 5-35 presents the evolution of passengers transported and percentage of "officially delayed" flights. Demand is still recovering at a slow growing rate, and the growth in delays over operations seems to accompany that increase on demand. Figure 5-36 presents the change of the delay sources, being the main figure the high value of the Airport&NAS delays (around 14% in 2004 and 2005), the highest of the Top5 USA airports. The rest of the sources have low values, around 4%.

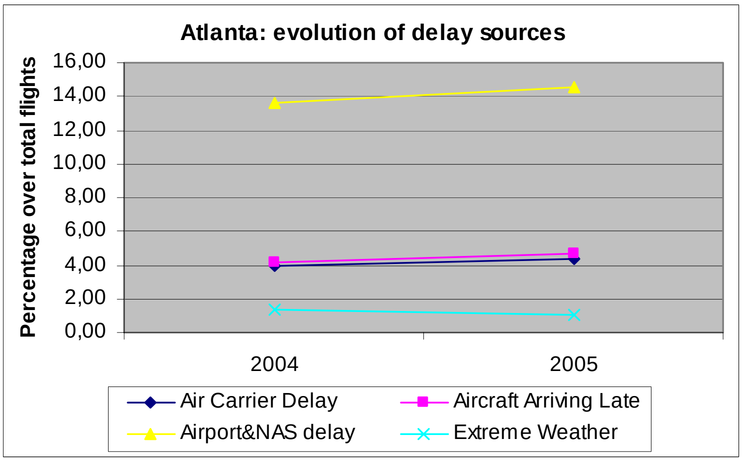
The Hartsfield-Jackson Atlanta airport has gone through a process of strong investment during the last decade, in order to adequate its capacity to the growing demand previous to 9/11 terrorist attacks. The most important works included the modernisation of the passenger terminal and the entry into service of the 5th runway and new control tower. The modernisation plan was launched in 1999 with a global investment of 5.4 billion US dollar in a 10-year development program, still running.

Given the evolution of the delay sources, the large investments capacity and the still low growth of air transport demand, it could be said that the Atlanta airport is not congested at this moment. In fact, its 1999 development programme was designed for traffic forecasts according to variables pre 9/11, which means that the ground capacity might well be sufficient for the present traffic levels (see Figure 5-26). However, the high value of the Airport&NAS delays can cast a shadow of congestion. It is important to remember that Hartsfield-Jackson is the busiest airport of the world, with almost 1 million operations per year.



Source: own elaboration from BTS data

Figure 5-35 – Atlanta: comparison between passenger and delayed flights growth



Source: own elaboration from BTS data

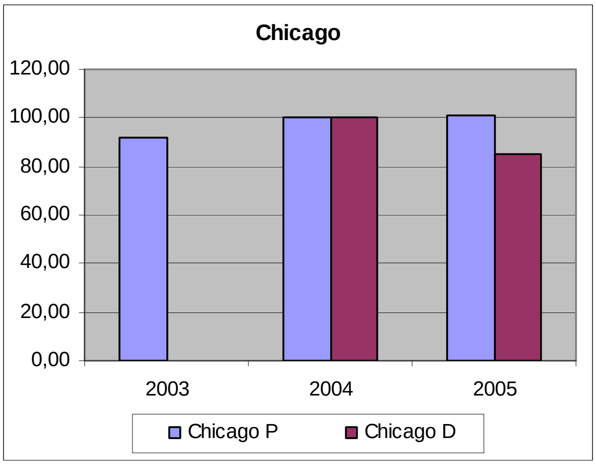
Figure 5-36 – Atlanta: evolution of delay sources

5.5.2 Chicago

The Chicago O'Hare airport presents a very significant reduction of the percentage of delayed flights in 2005, about 20% (see Figure 5-37) following a trend concerning passengers transported (see Figure 5-26) of recovery from the 2001 results.

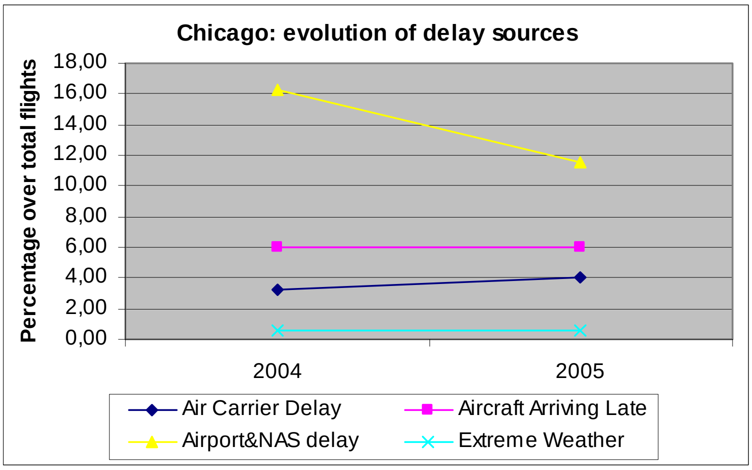
The most important source of delays in 2004 and 2005 was, as in Atlanta, Airport&NAS although with an important reduction. Aircraft arriving late has a value of 6% in the period, which could be taken as the medium value for the Top5 USA airports. The airline source of delay is quite low, under 4%.

The Chicago O'Hare airport does not provide on-line information concerning investment policy or works underway. This turns difficult to evaluate properly the capacity status of this airport. Taken in the context of the USA airport system, with the recent recovery of traffics and the overall situation of capacity in the rest of the large infrastructures, it is quite likely that the Chicago airport does not suffer from congestion at this moment.



Source: own elaboration from BTS data

Figure 5-37 – Chicago: comparison between passenger and delayed flights growth



Source: own elaboration from BTS data

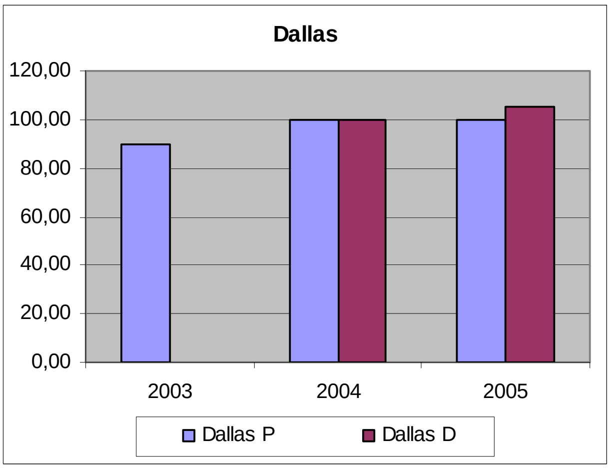
Figure 5-38 – Chicago: evolution of delay sources

5.5.3 Dallas

The Dallas-Fort Worth airport has not yet recovered the pre 2001 traffic levels (see Figure 5-26). Compared with Chicago and Atlanta, Dallas airport has very low percentages of delayed flight per source (see Figure 5-40): Airport&NAS is under 7%, as well as aircraft arriving late (5.5% average) and air carrier (below 4%). Concerning the evolution of the passengers and percentage of delay index, the slight rises since 2003 of passengers transported seem to be accompanied by an increase in delays between 2004 and 2005.

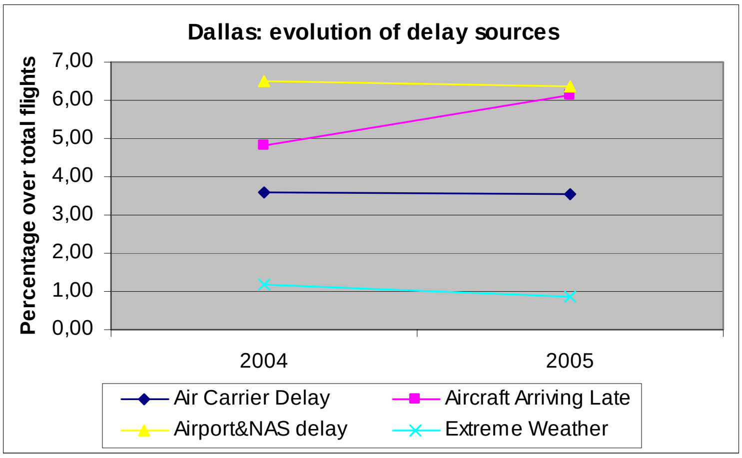
Like in many other USA airports, Dallas-Fort Worth launched by the end of the 90s an investment programme to keep up with the forecasted demand rise of the 21st Century[13]. The 2001 air industry crisis is still affecting Dallas, that has not recovered the 2000 traffic record. This means that Dallas-Fort Worth should be by now (the investment plan should be on its last stages) with an infrastructure over the required capacity to attend the real demand.

13 In total, Dallas-Fort Worth infrastructure and capacity investment would be of 134 million USD.



Source: own elaboration from BTS data

Figure 5-39 – Dallas: comparison between passenger and delayed flights growth



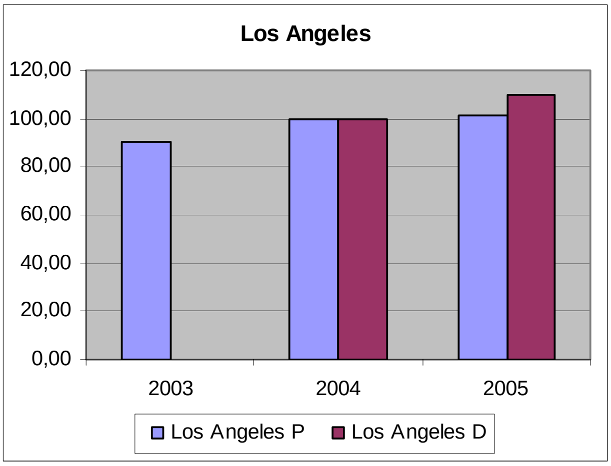
Source: own elaboration from BTS data

Figure 5-40 – Dallas: evolution of delay sources

5.5.4 Los Angeles

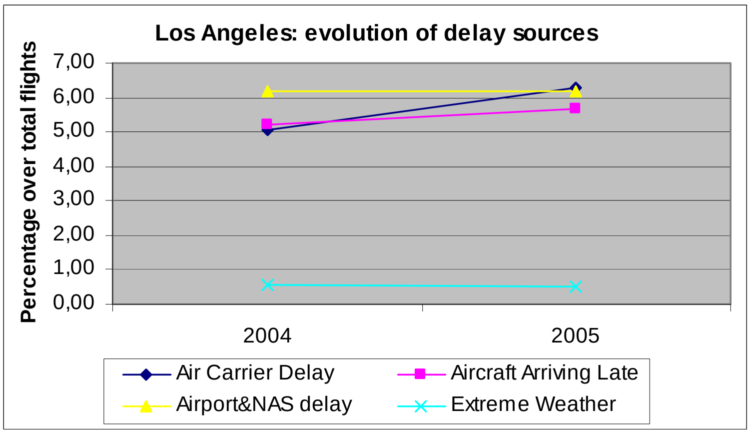
At this moment Los Angeles airport is still recovering the 2000 traffic levels (see Figure 5-26) but the increase of 2005 was accompanied by an increase in the percentage of delayed operations (see Figure 5-41). In terms of the delay sources, they are quite constant with the exception of air carrier delays, that grow in 2005. Los Angeles airport has a significant percentage of delays from air carrier reasons, higher than the three bigger airports of the Top5.

The Los Angeles airport is in a different situation as the airports presented up to now. LAX is currently launching a large investment plan with a life span of 10 years which has for objective to accommodate by 2015 approximately 78.9 million passengers per year, 3.1 million tons of cargo and 2.300 daily operations. The investments planned seem to be a preparation for the expected recovery of the air transport industry in the USA. At this moment, and with the available data, it would be prudent to say that LAX airport is not suffering of significant congestion, given its traffic levels, situation of the industry and percentage of delayed operations.



Source: own elaboration from BTS data

Figure 5-41 – Los Angeles: comparison between passenger and delayed flights growth



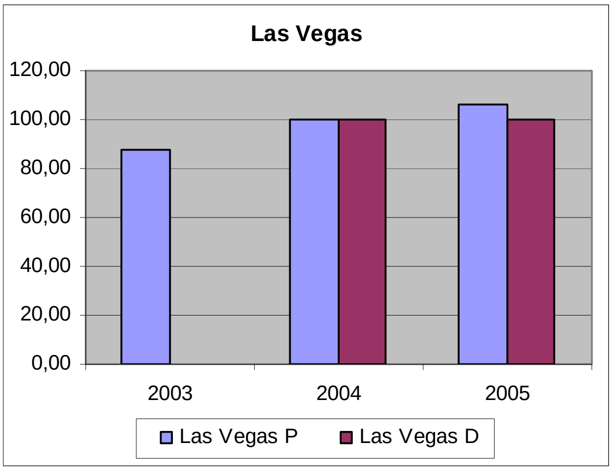
Source: own elaboration from BTS data

Figure 5-42 – Los Angeles: evolution of delay sources

5.5.5 Las Vegas

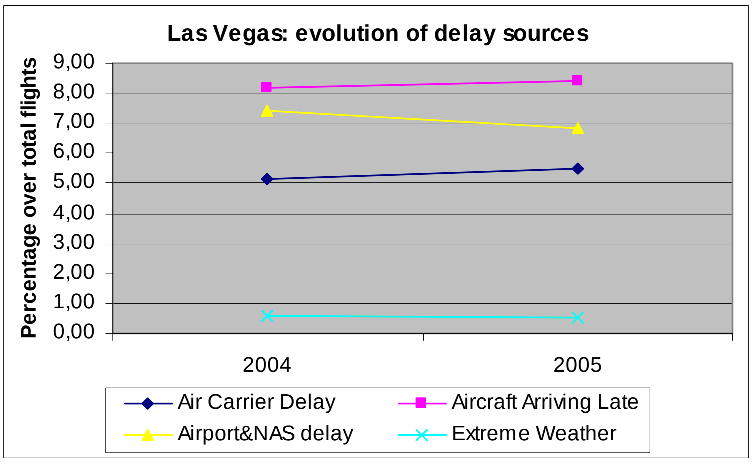
The Las Vegas-McCarran already recovered the 2000 traffic levels in 2003, having entered in 2005 in the Top5 USA airports (see Figure 5-26). The increase in passengers transported don't seem to be followed by increases in the percentage of delayed operations: Figure 5-43 shown that the percentage of delayed flights was constant between 2004 and 2005. Concerning the composition of delays (see Figure 5-44), the most important source of delay is late arrival of aircrafts, with low levels of Airport&NAS and air carrier delays, comparable to those from Los Angeles.

The Las Vegas-McCarran airport administration is currently preparing the new strategic plan for the development if the airport in the 2020 time horizon. However, this plan is not intended to overcome immediate necessities concerning capacity, as the maximum operational capacity declared by Las Vegas-McCarran is of 53 million annual passengers (the 2005 passenger figures were below 45 millions). The main works foreseen are the improvement of the passenger terminal and roadway system, in order to reach the 53 million passengers without problems of congestion. The Las Vegas airport, according to this information, does not suffer from congestion at this moment.



Source: own elaboration from BTS data

Figure 5-43 – Las Vegas: comparison between passenger and delayed flights growth

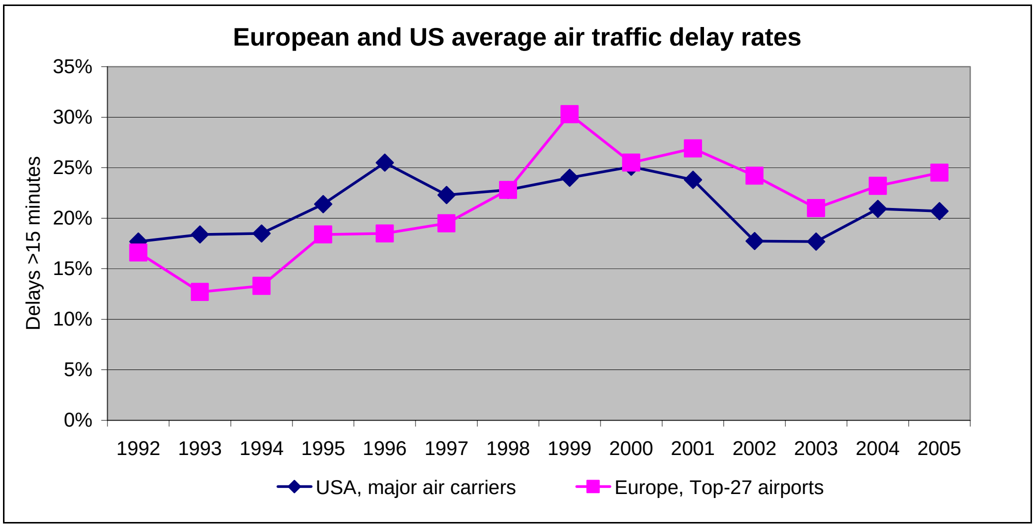


Source: own elaboration from BTS data

Figure 5-44 – Las Vegas: evolution of delay sources

5.6 Comparison between EU and US

Following the detailed analysis concerning delays and capacity per region and airport, in the following a comparison on delays between the USA and Europe is presented. The long term trends are illustrated by Figure 5-45. It shows that delay rates in the two regions across all airports are similar, but the EU development appears slightly more dynamic. While until the mid 1990s intra-European flights have been more on time, their punctuality has dropped significantly after the Kosovo conflict in 1999 and since then has remained worse compared to US punctuality figures.



Sources: BTS (2006) and AEA (2000 to 2006)

Figure 5-45: Long-term comparison between delay rates in US and European air transport

Further analysis is based in the figures condensed in Table 5-16 that provides the percentage of delayed operations and the percentage of participation of each delay source in the formation of delays. The table has been built using data from the Top5 airports of Europe and the USA.

Concerning the average value of the percentage of delays, it is clear that the European air transport system generated a higher percentage of delays over operations. This can be a clear indicator of higher congestion in Europe. This can be supported by the different contexts of both industries: the USA is going through an important crisis (not yet recovered from the 2001 events) and has a certain level of spare capacity in most airports; on the contrary, European industry has grown strongly in the last decade and its airports have been or still are quite congested, despite the efforts on investments for capacity.

Concerning the participation of the different sources of delay, the average shares are quite similar. The comparison has been performed aggregating European and USA categories according to the criterion resumed in Table 5-1. This criterion, although built according to the definitions and equivalencies of both systems, might have some background conceptual problems. For instance, the difference between airline and airport delays sources in the USA and Europe is quite significant. This can be related to the different organisation of the airport sector, or to the higher efficiency of USA airlines, or perhaps to a potential different account rule for delays between regions.

The "systemic delay" late arrival is higher in average in Europe. This can be a sign of a more congested sector, as late arrival comprises all delay causes. The difference in average is quite large and between the main airport of each region is more than double in the European case.

Table 5-16 – Resume of percentage of delayed flight and causes by airport and region

Region	Percentage of delays					Sources of delay 2005 (%)			
	2001	2002	2003	2004	2005	Airline	Airport	Weather	Late Arr.
EUROPE									
Average	**26.9**	**24.2**	**21.0**	**23.2**	**24.5**	**6.9**	**7.9**	**0.9**	**8.8**
London Heathrow	24.0	25.7	22.5	27.8	28.4	7.8	9.3	0.7	10.6
Paris CdG	30.3	26	24.4	22.7	25.0	7.9	8.7	0.8	7.6
Frankfurt	20.3	18	16.8	18.3	20.5	4.2	5.5	1.4	9.4
Madrid	32.4	30.2	21.5	23.3	25.3	6.1	10.2	0.5	8.5
Amsterdam	27.3	21.1	19.7	23.7	23.3	8.6	5.9	0.9	7.9
USA									
Average	**23.8**	**17.7**	**17.7**	**20.8**	**20.7**	**4.8**	**9.1**	**0.6**	**6.2**
Atlanta	:	:	:	23.2	24.5	4.3	14.5	0.6	4.6
Chicago	:	:	:	26.1	22.2	4.1	11.5	0.6	6.0
Los Angeles	:	:	:	17.0	18.7	6.3	6.2	0.5	5.7
Dallas	:	:	:	16.1	16.9	3.6	6.4	0.9	6.1
Las Vegas	:	:	:	21.4	21.3	5.5	6.9	0.5	8.4

Source: own elaboration from AEA and BTS data

5.6.1 Comparison of delay causes

The above analysis of the most busy European and US airports has shown, that the causes of delays may substantially diverge between airports and may change over time. Nevertheless, given similar categories of delays, which is the case for AEA and DOT consumer report, the overall comparison between Europe and the US shows a similar picture. Most decisive for the comparability of statistics is the treatment of reactionary delays and weather conditions. Table 5-17 shows the comparison between Eurocontrol and AEA analyses for Europe and sets the comparison to US statistics for 2005. The fitures highlight the effect of maintaining reactionary delays (AEA and DOT) vs. tracking them back for their original reasons (Eurocontrol).

Table 5-17: Comparison of delay causes between Europe and US 2005

Area	Europe		USA
Agency	Eurocontrol	AEA	DOT
Air carriers	50%	25%	30%
Air traffic management	34%	30%	35%
Weather	11%	4%	4%
Reactionary	0%	40%	30%
Others	5%	0%	0%

Values represent shares at delayed flights
Sources: Eurocontrol (2006); AEA (2006); DOT (2006)

5.7 Conclusions

The previous analyses lead to the following conclusions:

- The European air transport industry is following an important growth path, surpassing the growth rates in the USA. In fact, the European air transport system did not suffer as much as the US after the 2001 crisis. The USA air transport is still recovering to passenger and operation levels prior to the 9/11 terrorist attacks;

- In aggregate terms, it can be said that the European air transport system has low levels of congestion, leaving aside some specific airports. The US system is even less congested, due to the large capacity in place, built expecting higher traffic levels. In general, USA airports have very low congestion;
- Europe: percentage of delays fell after the Kosovo war (1999) that introduced large restrictions to air traffic. In 2004, in a scenario of traffic growth, congestion rose again. Regional flows are becoming more intense and delays (in total time and percentage of flights) are starting to rise.
- USA: the available data are very few and do not allow the analysis of trend. It seems that congestion is risen with traffic levels, but only in some airports (the largest) and capacity is still available even in the largest hubs;

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6 Case Study on European and US Seaports

This report combines the results obtained from both a survey held among various actors in and/or related to sea ports and a review of existing literature on the matter, especially with regard to quantification of existing congestion problems in sea ports.

The survey combined a paper questionnaire sent out, supplemented by a telephone survey to complete or clarify respondents' answers. In some cases, telephone answers were the only source of reaction as completing the written questionnaire often turned out to be a demanding exercise. Out of the total of 32 contact persons that formally confirmed over the telephone to transfer their answers to the researchers, finally 26 effectively sent in their paper questionnaire and/or answered by phone. This number should be sufficient to draw significant conclusions. The validity of the answers is strengthened by the representativeness of the answers: respondents cover various businesses, from port authorities over cargo-handling companies and shipping companies to rail and inland navigation operators. Annex I provides an overview of all respondents and their affiliations. Annex II gives the detail of the answers given by each respondent.

The literature review makes reference to a number of publications which assess actual congestion levels and/or provide insight in its determinants and possible policies to relieve the problem. Annex III provides full bibliographical references to the publications referred to in the following paragraphs.

In the following sections, the results of both the survey and the literature review are dealt with on a thematic basis. Questions deal with more fundamental issues like the definition and the measurement of congestion in sea ports, as well as with more operational issues like actual congestion levels and policies.

6.1 Delay monitoring

6.1.1 Methods for measuring traffic conditions

From the part of the cargo-handling companies, it can be said that in general congestion measurement is performed. In some cases, e.g. PSA & P&O Ports, congestion measurement is combined with overall productivity measurement. Most of the time, congestion measurement is restricted to congestion at the operator's premises. In some cases, like in Aarhus, at APM Terminals, at Rauma Stevedoring and in Zeebruges, it takes into account ship time on terminal.

No congestion measurement seems to be done by governments, especially not in the countries directly questioned (Belgium and Portugal). Neither do port associations perform any congestion measurement, as confirmed by British Ports Association. Shipping companies, like Gearbulk, perform measurement, which in general includes more than port congestion.

Port authorities are quite diverse in their measurement efforts. Some do measure congestion as such systematically, for ships leaving (Antwerp), or total ship time in port (Antwerp - Corck - Hamburg - Humber Sea Terminal – Kotka – London - Zeebrugge), or commodity time in port (Barcelona), or ship time on terminal (Kotka - Marseille). Some ports, like Tacoma, measure overall capacity use. Ports like Long Beach, Portuguese ports and Rauma) perform measurement in an unstructured way. No measurement is done at for instance Gdynia, Genova, Miami, Rostock or Rotterdam. Some combined port authorities / cargo-handling companies, like in Felixstowe, measure whether ships meet time slots.

6.1.2 Scope, frequency and costs of data akquisition

Cargo-handling companies do measure congestion for every ship. Measurement is then done either at the overall terminal level, from shift to shift, or at the terminal gate, from hour to hour, or at the ship itself, on a ship by ship basis. The latter is often contractually stated in contracts between e.g. PSA, P&O Ports and Rauma Stevedoring on the one hand and shipping companies on the other hand. Shipping companies like Gearbulk themselves equally measure congestion for all vessels on all calls.

Port authorities too sometimes measure congestion for every vessel and for every call, like in Antwerp, Humber Sea Terminal, Kotka, London and Zeebruges. In other cases, measurement is done in the maritime section and at the terminal, like in Marseille. Some ports exclude the terminal and the hinterland from their analysis, like e.g. London. For some ports, locks are important infrastructure elements, like in Antwerp, and their congestion features are therefore included in overall measurement. Some ports leave congestion measurement to the operator for their premises, like does the port of Aarhus. Hinterland congestion measurement is done in Barcelona.

6.1.3 Data Differentiation

Most cargo-handling companies measure congestion per terminal element, like e.g. PSA and P&O Ports. Port authorities have their measurements per vessel, as for instance in London or Antwerp, or per commodity, like in Barcelona and Marseille.

6.1.4 Publication of data

For all actors surveyed, measurement results are kept internal. Only the port authority of Barcelona confirmed that they made results public through studies, be it on an irregular basis.

6.2 Delay assessment

6.2.1 Definitions and processing of delay data

Cargo handling companies define congestion as a more than average window spread, like does P&O Ports, or as the supplementary time to get commodities through terminal, like in the case of Rauma Stevedoring. The two most important elements assessed by for instance PSA are quay and yard. For the quay, the main question is: "do ships have to wait at berth?" For the yard, cargo-handling companies mainly ask whether there are not too many shifting moves? Second to quay and yard is the situation of trucks and barges. For trucks, cargo-handling companies are mainly interested in whether trucks have to wait at quay. One hour turnaround time seems to unacceptable in most cases. For barges, a similar question prevails, although acceptable waiting times are usually longer here.

At government level, congestion is defined broadly as the extra time that is required for operations in general compared to normal time, as is done in Portugal.

Port authorities may use different definitions of congestion. In a broad sense, congestion is defined as a situation where capacity cannot follow throughput growth, as it is used in Tacoma. Alternatively, the definition may refer to the extra time that is required compared to normal time, as is applied in Aarhus, Felixstowe, Kotka, London and the UK ports in general, and Zeebruges). Furthermore, reference may be made to the fact that too many ships experience external factors that prevent normal operations, like the definition is used in Kotka. Congestion can also be defined as a state where ships or hinterland modes have to wait, like the Port of Miami does. Another possibility is to define congestion as ships having to wait to be able to berth, as the Port of Marseille does. Finally, congestion can be defined according to a method applied by engineering or management staff. In the Port of Antwerp, reference is made to former HesseNoordNatie head engineer Eric D'Hondt who stated that "congestion occurs if once per month 5% of ships have to wait for three hours at least". Next to the previous, broad definitions, congestion may only involve ships, like it does in Gdynia and Rauma. Finally, some ports apply no strict definition at all, like for instance Barcelona, Corck, Genova, Hamburg, Humber Sea Terminal, Long Beach and Rostock).

Shipping companies, like Gearbulk, similarly to some ports, refer to congestion as a situation where too many ships go through external factors that prevent normal operations.

6.2.2 Key results of traffic congestion studies?

Among the **cargo-handling companies,** PSA confers that if a terminal is at capacity, there is permanent congestion on the terminal. At sea side, there seem to be weekly peaks. At Rauma Stevedoring, congestion is observed at peak moments. The UK port association confirms that on its territory, there was congestion in the past (2004), but the problem is now solved, except for ro/ro, where congestion remains.

The port congestion landscape as stated by **port companies** seems to be quite diverse, to the extent that some ports and terminals seem to experience no congestion at all, whereas others are confronted with extreme congestion, and still others are in an intermediate situation. Hamburg is among the ports that clearly state that congestion occurs. For other ports, congestion is stated to be a problem on land side, due to for instance old gates, construction works, a gate location too close to the port entrance, trucks moving through the city and cruise ship priority on land, like in Miami, or due to tourism traffic, like in Zeebruges, or due to bad rail service, like in Tacoma. In most other US ports, truck/gate congestion is observed as a major problem.

The ports of Rostock and Corck observe terminal and hinterland congestion. In the case of Corck, the worst hit is inland navigation. Barcelona and Rotterdam mention road handling and road transport near port as an issue. Measurement in both cases is done by hinterland modes. At Long Beach, road and previously also rail – due to positioning problems – as well as the terminals experience congestion. At the terminal, main congestion causes are labour shortage and a lack of off-shore backup. The port of Aarhus experiences similar problems as those in Long Beach, be it only at the terminal.

In Marseille, congestion seems to be confined to tankers. In Kotka, only customs seem to be hit by congestion. P&O Ports reports problems only at its gates. At its Antwerp terminals, in

2004, 40% of all gate traffic passed in one hour on a total of 18 opening hours a day, with consequences mainly for inland navigation.

Ports where congestion seems to occur from time to time are Antwerp, Rotterdam and Felixstowe. In the latter two cases, congestion is often caused by extreme weather circumstances, and in the particular case of Felixstowe by heavy winds. No structural congestion on the sea side was reported at London, especially for liner services, and in the case of Rotterdam, where the ship always has priority to other chain elements. No congestion at all was reported in Gdynia, Genova, Humber Sea Terminal, Portuguese sea ports and Rauma)

Shipping companies like Gearbulk generally observe a lot of congestion, in function of the time of the day, year, etc.

That congestion is indeed a issue a many sea ports, is demonstrated in for instance World Cargo News Online (2002, 2004b and 2005) which report congestion at respectively the overall port level in Yantian, Rotterdam – 72 hours barge waiting time at ECT and 45 at the Maasvlakte terminals - and at rail connections in South California. Staake (2005), CEO at Duisburg Hafen, reports barge waiting times of up to 60 hours. Whatley et al. (2006) notify 35 vessels, equivalent to 17,200 TEU of cargo, waiting for entering the port.

6.2.3 Most congested network parts, time periods and user groups?

According to **cargo-handling companies'** opinion, quay and yard (PSA), gates (P&O Ports and Rauma Stevedoring), the hinterland (P&O Ports, Tacoma and the UK ports) as well as the maritime entrance (Zeebruges) can all be very congested network parts.

Port authorities report the hinterland in general to be a congestion problem unit. In particular, problems can be located at city centres (Miami), hinterland connections (Barcelona, London, Long Beach, Rostock and Rotterdam), rail (Barcelona), inland navigation (Antwerp) or specifically during weekends (Antwerp). The terminal is stated to be a problem in Aarhus, Gdynia, Hamburg, Rauma and Rotterdam. Containers (Hamburg). Gates are problematic in Rostock, whereas the maritime entrance is reported to be troublesome in Marseille.

Among **shipping companies,** the maritime entrance is experienced to cause most problems, not the terminal.

6.3 Projected development and key drivers of ship delays

Cargo-handling companies differ in their answers to the future of congestion. Some, like PSA, expect a worsening on the terminal. Ohters, like Rauma Stevedoring, expect no worsening. Port associations in the UK expect a worsening if no measures taken.

Among **port authorities,** some expect a worsening, like Corck, Long Beach and Rotterdam. Miami expects deterioration for cargo as well as cruise vessels. The port of London foresees worsening congestion in its hinterland. Rostock has similar forecasts, especially for road disclosure of the port, with effect on the terminal. Genova expects a worsening on the road side through bad truck scheduling. Rail could be a problem there if no capacity extension is provided. Congestion in neighbouring ports and the consequent divergence of traffic may cause new congestion problems, as reported by for instance Aarhus, where a 25% growth due to the Bremerhaven congestion is reported - compared to 5/6% normally. The situation in Aarhus could even get worse if Maersk would have a direct line to China. Some ports, like Marseille, foresee a worsening for new cargo types, for instance containers.

Other ports only schedule a worsening if no measures would be taken. Gdynia, and Tacoma are both in this case. P&O Ports has similar prospects, be it only at its terminals. At sea, congestion would remain rather accidenta, whereas on land, it would be structural

No worsening at all is expected in at the Humber Sea Terminal, at Kotka and at Rauma. Major improvements are scheduled in each of these ports. With respect to the: terminal: new quays would be built and better worker regulations would be installed. On the trucking side, traffic spreading would be applied. For rail, new infrastructure would become available and privatization would be enforced. Inland navigation finally in some cases is good and stable, like in Antwerp, or unwanted improvements may occur due to negative events; like shipping lines leaving, so that traffic decreases, as was the case in Zeebruges.

Shipping companies expect that in some ports in general, congestion will get worse.

Illustration of key congestion drivers is given by World Cargo News Online (2005c and 2005e), where lack of space is reported for North West American ports respectively a number of factors are indicated for Australian port congestion.

A list of key drivers mentioned in academic literature is given in Table 6-1. The drivers mentioned by respondents from the survey seem to agree with these drivers.

Table 6-1: key drivers of sea port congestion

Terminal capacity	*Burns (2005), Smith (2005), Staake (2005), Escutia (2005), Bourne (2005), Avierinos (2005), Blomme (2005), Whatley* et al. *(2006)*
Dwell time	*Smith (2005), Smith (2005), Escutia (2005), Avierinos (2005), Blomme (2005)*
Demand / Traffic volume	*Penfold (2005), Smith (Z005), Harnack (2005), Bourne (2005)*
Environmental concerns	*Penfold (2005), Burns (2005), Smith (2005), Avierinos (2005)*
Rail	*Bookman (1996), Smith (2005), Traill (2005), Blomme (2005)*

Road	*Bookman (1996), Traill (2005), Blomme (2005)*
Business hours	*Smith (2005), Traill (2005), Blomme (2005)*
Ship size	*Penfold (2005), Visser (2005), Avierinos (2005)*
Truck driver availability	*Smith (2005), Traill (2005), Avierinos (2005)*
Hinterland connections	*Penfold (2005), Burns (2005)*
Reliability	*Harnack (2005), Bourne (2005)*
Modal shift	*Burns (2005), Staake (2005)*
Cranes	*Bookman (1996), Visser (2005)*
Weather	*Financial Express (2006)*
Technology	*McLaughlin and Davidson (2001)*
Investment	*Escutia (2005)*

6.4 Policy options

Cargo-handling companies plan for instance automation, like at Rauma Stevedoring at the gates), better communication, including truck pre-announcement, better hinterland access, like in Antwerp, improved maritime access and locks, as in Antwerp and Zeebruges, new roads, like in Zeebruges where lobbying is going on, or terminal capacity extension at the yard, where more space would be made available, or at the quay, where new cranes would be installed). Eventually also new terminals are scheduled, like in Antwerp, where a doubling of capacity is needed as Rotterdam as well as German ports lack capacity, so an overflow is expected to come to Antwerp. According to theUK **port association,** in the Freight Trade Association, a code of practice has been agreed upon.
Among **shipping companies:** congestion-beating plans exist, but depend on the level of congestion, and on specific ports.

Port authorities finally plan barge traffic services, like in Antwerp, better communication with neighbouring communities, like in Long Beach, or gate complex enlargement, like in Miami - from 5 to 10 gates. ICT is considered to be helpful in relieving congestion in Antwerp, where Seagha allows real-time assignment, with registration of starting and ending time. Humber Sea Terminal monitors gate as well as terminal capacity on a constant basis. Gdynia works on better hinterland connections, whereas Rostock plans to improve communication with road authorities. In Miami, a new port access tunnel is under way. Antwerp is planning for new rail access. The Port of Barcelona currently negotiates better rail integration through the FERMED project, requiring no new infrastructure as well as no financing. Similare initiatives were started in Genova, Rotterdam and Tacoma, where a Freight Action Strategy was agreed upon. P&O Ports urges for a better modal mix, whereas also the Port of Rotterdam expresses its desire to come to a better modal mix. The port of Corck stresses a better maritime access. The Port of Antwerp wants to improve its social regulations. Terminal extension as a last solution is announced in Aarhus and Marseille - although unsure in the latter case, due to limited funding. No plans are currently held in Felixstowe, Genova – where the port master plan is at standstill, Hamburg, Kotka, Portuguese ports and Rauma.

Examples of policies brought into practice are reported by World Cargo News Online (2004, 2004c, 2005b, 2005d and 2005f), where the port authority created inland container handling deports respectively traffic diversion was applied by shipping lines away from Los Angeles, more labour was added in North Western American ports, traffic diversion was applied by MOL and better rail connections were provided by the railway operator.

7 Synthesis of the COMPETE country reviews

7.1 Classification of congestion levels

The following tables contain very brief characterisations of issues on traffic quality measurement, the current state of congestion of delays, the future expectation of the delay situation and policy plans envisaged to fight congestion for the six modes of transport and for each of the 27 countries investigated. The data has exclusively been retrieved out of the COMPETE country reviews (Annex 3) and the specific study on European and US seaports.

In order to provide a quick and intuitive picture of the congestion situation and its predicted development two intuitive sets of indicators have been generated:

- The LOS indicator (A to E) indicates the characteristic, severity and concentration of congestion across national or urban networks.
- The slope indicator (↗↗ to ↘↘) expresses the expected development of service levels (traffic quality) in the future.

The exact definition of the two indicators are given in Table 7-2 and Table 7-2 below.

Table 7-1: Definition of the LOS-indicator

LOS	Description
A	No congestion or only at a few days of the year. e. g. at holidays or at a limited number of locations
B	Regular congestion at selective hot spots, e. g. at entrance / exit points of motorways or at particular junctions
C	There is some regular congestion on several parts of the network. which is, however, not considered severe
D	Some parts of the network are regularly heavily congested; other factors, such as insufficient network quality, regular maintenance quality or high accident risks are considerable.
E	Regular recurring congestion due to insufficient network capacity at wider parts of the network at the majority of days

Table 7-2: Definition of the slope indicator

Slope	Description
↗↗	Strong improvement of traffic conditions: Congestion levels are expected to considerably decrease across the entire network or to strongly increase or to be removed in some critical hot spots
↗	Improvement of traffic conditions: Congestion levels are expected to gradually decrease, but not to be removed, on the entire network or in some neuralgic hot spots in the future
→	No significant change in congestion levels on major parts of the transport networks in the future
↘	Moderate decline of traffic conditions: Congestion levels are expected to slightly increase on the entire network or increases concentrate on specific network parts in the future
↘↘	Strong decline in traffic conditions: Congestion levels are expected to drastically increase on many or all parts of the network in the future

Table 7-4 presents an overview of the classifications by mode and country for those cases where data is available. The subsequent tables (Table 7-5 to Table 7-10) eventually present the detailed evaluation of the COMPETE questionnaires.

7.2 Summary panorama of congestion

Table 7-3:Synthesis of country reviews - inter-urban road

Country	Inter-urban road	Urban road	Urban public transport	Rail	Air	Waterborne transport
US	B ↘	D ↘	D ↘	D ↘	B ↗	D ↘
Germany	D ↘↘	C →	B →	C ↗	C ↗	B →
France	C ↘	D ↘↘	C	D ↘	D ↘	A ↘
UK	D →	E ↘	B →	C →		B →
Italy	C ↘	D ↘	C →	C →	C →	B →
Spain	B →	D ↘		A ↗	B →	B →
Poland	D ↘↘	B ↘↘		C →	C ↘↘	A ↘
Nether-lands	E ↘↘			D ↗		D ↘↘
Greece	B →	E ↘↘		B ↘	C ↗	
Portugal	C ↗↗	D ↗↗			C ↘	A →
Belgium	B →	C ↗		A →		B ↗
Czech Rep.	C ↘	E ↘↘		C →	B ↘	
Hungary	B ↘	E ↘	D →		D ↘↘	
Sweden	A →	C ↗		B ↗		A →
Austria	C ↘	C ↘	C →	C →	C →	
Switzer-land	A →	B →	B →	B ↗	C →	
Denmark	B	B	B	B ↗		B ↘
Slovakia	D ↘↘	C ↘	C ↘	D →	A →	
Finland	A →	C ↘		B ↗		A →
Ireland	B ↘	C →	C →	A ↗		
Lithuania	B			C ↗	A ↘	
Latvia				A ↘	A ↘	
Slovenia	B ↘	B ↘		C ↗		
Estonia		B				
Cyprus	B →	C →	C →	Not applica-ble	B	A ↘
Luxem-bourg	B ↘	B ↘				
Malta	A	C	C	Not applica-ble	A →	

7.3 Synthesis of country reviews by mode

Table 7-4: Synthesis of country reviews - inter-urban road

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
United States	Demand data modelling around agglomerations and at highway intersections. Steady monitoring of 85 cities since 1982	Serious congestion on interstate highway crossings and where congestion is caused by metropolitan areas	Increase due to lag of grade-separated junctions and access points. Particular problem for port access traffic.	According to safetea-lu: Capacity expansion investments, real time system management; road pricing, high occupancy vehicle lanes.	B ↘
Germany	Detailed demand data assessment by weather and topology, floating car data	Highly congested: Ruhr area and around big agglomerations (Berlin, Hamburg, Munich)	Increase congested links from 31% (2000) to 42% (2015)	2003 investment plan, time variation of HGV toll, traffic shift to rail and waterways	D ↘↘
France	National system of induction loops, camera-based incident detection systems. Steady monitoring at Ile-de-France	Many motorways are currently on the way of saturation. They support the main part of the international transit traffic.	Analysis for the PACA region indicate increases of average travel time up to 30%.	Road Pricing, modal shift and intermodal capacity …	C ↘
United Kingdom	Regular speed measurement with floating cars plus demand data modelling	Congestion perceived a major issue by government particularly in England	Policy measures are assumed to keep congestion levels stable	10 year plan: Target to reduce road congestion; no concrete reduction limit	D →
Italy	Statistics recorded by motorway concessionaires, publication via real-time traffic information system only.	No information - only 1995 data for parts of the network available	No information	Local level (e.g. Road Pricing and Traffic management in Rome and Milano)	C ↘
Spain	National statistics gathered in counting points through the network. Also main highways around Madrid have traffic CCTV and on-line traffic facilities	Low congestion in most of the network, with several bottlenecks. High traffic intensity in peak periods (holidays).	Motorisation rate in Sapin continues to grow, with almost no alternatives from public transports (mid and long range trains)	Strong expansion of high capacity roads in Spain in the next 10 years, will increase largely capacity of the network	B →
Poland	Induction loop data and manual counts. No congestion computation	Congestion problem at agglomerations; roads of generally very bad quality		Construction of bypass routes around cities	D ↘↘
Netherlands	Manual and electronic incident and traffic jam detection and evaluation	Particular problem in the densely populated Randstad region and around other cities	Further increase due to rise in freight traffic from Dutch and Belgium seaports	Possibly road pricing, investment (to be further evaluated)	E ↘↘
Greece	Study called "Traffic Management of Greek Motorways - System of Measurements of Road Traffic (SMOK) EGNATIA traffic counting system	Only in specific parts under construction in fairy days and some weeks in summer	No congestion predicted in the next 10-15 years	Motorways creation though concessions	B →
Portugal	Automatic counting on motorways, Manual counts 1 to 5 years	Main problems at radio routes around Lisbon and Porto, Access to major ports	Complementary Itineraries in the two metropolitan areas, problems will be considerably diminished.	Programmed investment increase; intelligent system of information and traffic management	C ↗↗

Belgium	Magnetic counts on motorways, occasional counts at other roads (cameras, rubber tubes)	Minor problem, 7.5% of motorways congested in peak; Ringroads Brussels and Anvers	De-coupling of traffic growth and economic development; stagnating of demand in Brussels	Road pricing; dynamic traffic management, free public transport; fuel pricing; rail and air capacity extensions	B →
Czech Republic	Monthly pick-up of induction loop data; 5 year manual counts. No congestion recording	Overloaded motorways: D1 Prague- Brno - Vyskov, D5 Prague-Plzen-Rozvadov/ Waidhaus (Germany) and R1 Prague ring road	Steadily growing motorisation and demand, involving growing congestion.	ITS for road traffic management, Network development, priorities for links to Germany and Poland	C ↘
Hungary	Dense network of counting posts on all roads. Evaluation every 1 to 5 years.	Budapest ring and ingoing (M3), Budapest-Ballaton on holidays	Doubling of traffic until 2030 with growing congestion	Intensive high speed road network development, bridges, connection roads and Budapest ring road	B ↘
Sweden	Traffic sensors serving a national ITS system for traffic control and information	No significant congestions on motorways except in and around bigger cities	No worsening envisaged	TREN projects, in particular the Nordic Triangle	A →
Austria	Measurement of current against usual traffic conditions; Instant online publication in the Austrian Traffic Barometer"	Brenner corridor due to HGV transit; car congestion only around cities and during summer holidays	No final information; probably steadily growing due to steady rise in lorry traffic across the Alps.	No information	C ↘
Switzerland	Induction loops, incident recording by private actors/Road Office, speed measuring on north-south axis via mobile phone tracking data	Minor congestion problems. Significant traffic jams appear mainly at city borders and in holiday periods	Traffic growth mainly of passenger cars will lead to increased problems mainly at urban bypasses.	Network capacity investment plans in political discussion, with new financing schemes.	A ↘
Denmark	Assessment of motorway traffic quality by the 2004 Copenhagen congestion study	Only slight congestion around Copenhagen	No information	No information	B
Slovakia	Manual traffic counts since 1963, 2005 national census	Problems: through traffic through district towns, construction works. 3 major highway bottlenecks	Alarming growth driven by GDP development, decrease of P.T. modal share and growing motorisation	Priorities: TEN-T development, improved quality of public transport, construction of bypass roads	D ↘↘
Finland	Systems for permanent traffic count, travel times and general travel census	Few times per year on holidays on limited network part due to poor geometry of 2 lane roads	No information, but due to Finland's remote location no dramatic change expected	New capacity; traffic management services; reduction of speed limits from 100 kph to 80 kph	A →
Ireland	Regular monitoring on road users experience; automated traffic counters, visual counts for road monitoring.	Widening of morning peaks; M15 operating at or above capacity limits in morning peak	Steady increase of truck traffic predicted	No detailed information	B ↘
Lithuania	Automatic counting posts, manual traffic counts, enquiries and video cameras	Most of inter-urban road network is congestion free. Some problems in summer and some congestion near Vilnius	No information	Reconstruction and upgrading of existing roads engaged in international carriages	B
Latvia	No information	No information	No information	No information	
Slovenia	Automatic microwave, video and induction loop detection; manual counts; congestion analysis by micro simulation models	Congestion at motorway branches, arterials and toll stations in peak and holidays;	Increase mainly at urban arterials fostered by economic growth; partly compensated by congestion control.	Completion of the motorway systems; intelligent informaton systems;	B ↘

Estonia	No information	No information	No information	No information	
Cyprus	Annual Census planned: classification percentages, daily traffic estimates and lengths of segments for all roads	Most congested segments on the inter-urban roads are the approaches to the cities on the motorway network	no any requirement for a specific traffic study	Reduction of road fatalities by 50%, sustainability and modal shifts. No specific policy on congestion.	**B** ➔
Luxem-bourg	Automatic counts on all motorways published online; LOS information available	Traffic jam at peak hours on main roads border crossings due to commuter traffic	No specific congestion forecasts; 30% traffic increase to 2020; cross-border +3% p.a.	Optimised used of existing roads; improve cross-border P. T. and intermodal freight transport	**B** ↘
Malta	No information	Congestion problems are limited to urban roads	No information	Ambitious road upgrade programme in the centre of the island to TEN-T standards;	**A**

Table 7-5: Synthesis of country reviews - urban road

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
United States	Archived flow data from Highway Performance Monitoring System: Steady monitoring of several indices back to 1982	Steadily increasing in spread and severity, but not perceived a major problem, even in large metropolitan areas	Congestion continues to grow; transport improvements do not keep pace with demand growth; but not perceived no. one problem by citizens	According to safetea-lu: Capacity expansion investments; real time system management; road pricing, high occupancy vehicle lanes	D ↘
Germany	Application of floating car data in Berlin, Nurnberg and Frankfurt	Some perception only in bigger cities (Berlin, Hamburg, Munich, Cologne).	Due to demographical development no significant change expected	Parking policy, public transport promotion, construction of urban bypass roads	C →
France	Steady measurement of incidents by cause and travel speeds in Ile-de-France	Major urban bottlenecks are the regions of Paris, Lyon and Bordeaux.	Increased severity. The impact of road development is low compared to the increase of road traffic.	Controle of local mobility, parking policy, controle of urban sprawl	D ↘↘
United Kingdom	Regular speed measurement for English cities. Use of flow data in Scotland	Greater London area highly congested; other cities rather modest	No congestion forecasts available, but increasing traffic demand predicted	Further development of urban road pricing, stabilisation of congestion levels	E ↘
Italy	Publication of traffic flow measurement in online traffic map for Rome	Major cities are heavily congested	No congestion forecasts available, but increasing traffic demand predicted	Road Pricing schemes for major cities (Rome, Milan)	D ↘
Spain	Measured in the major cities through traffic control systems. On-line facilities for surveying the networs are available	Important congestion in Madrid, Barcelona and other cities over 500.000 inhabitants. Some cities under 500.000 also congested	Expected moderate increase and further negative effects on mobility	National transport plans include the improvement of urban mobility as a main target. Combined policies on pricing and enhancement of public transports	D ↘
Poland	Induction loop (no assessment), periodic manual counts	Moderate congestion problem, Morning and evening rush hours; missing bypass roads	Strong increase of traffic levels due to fastly growing motorisation rate	Huge programme for constructing bypass roads	B ↘↘
Netherlands	No information	No information	No information	No information	
Greece (Athens, Attica region)	Continuous incident and speed detection by loops and cameras, toll station counts	Athens / Attica region: Entrance and exit points of motorways Urban network has reached its capacity limit during peak	Lengthening of peak hours in morning, noon and evening due to increased motorisation and urbanisation	Self-financing construction works, improvement of traffic lights regulation	E ↘↘
Portugal (Lisbon, Porto)	No information; Use of GERTRUDE traffic system co-ordinating traffic lights	The main hotspots are the agglomerations of Lisbon and Porto	Complementary Itineraries in the two metropolitan areas, problems will be considerably diminished.	Installation of intelligent systems of information and traffic management (road telematics)	D ↗↗
Belgium	Magnetic loops and rubber tubes (50% of road network); regular and occasional traffic counts. Capacity use published via internet.	Ring roads Brussels / Anvers and some others. Less relevant for local urban roads.	Decrease of congestion levels in some cities	Publication of real travel speeds on specific routes; covering the costs for P. T. season tickets for employers.	C ↗
Czech Republic (Prague)	Cordon survey, floating car data for speed detection, TV control for congestion detection	Very big Problem in Prague, traffic spreads to off-peak periods	Congestion becomes more frequent and always larger and longer.	Traffic flow dependent signalling, Traffic information system, new part of Prague ring road	E ↘↘
Hungary (Budapest)	No extended counting system. 28 detectors at important cross	Whole network congested early morning to late afternoon. Also	General forecasts difficult. Assumption: further increase ac-	Installation of roundabouts instead of signals, driver informa-	E

	sections.	problems in other cities	cording to general traffic evolution.	tion systems	↘
Sweden (Stock-holm)	Speed measurement by test drivers plus incident detection and inductive loops.	Moderate congestion in Stockholm even before the introduction of the congestion charging trial	Improvement of traffic conditions due to congestion charging scheme	Steady introduction of city toll system	C ↗
Austria (Vienna)	Continuous speed detection via floating car data. Instant online publication by pre-defined routes	Typical peak hour congestion. Also in other cities (e. g. Salzburg)	No information	No information	
Switzer-land (Zurich)	Automatic detection of traffic conditions via mobile phone data. Unified web publication for five cities	Mainly problem of access points. Traffic regulation keeps city centre generally congestion free. Regular congestion at by-passes.	No significant worsening of situation in inner urban areas expected. Increasing problems at urban bypasses	Introduction of improved traffic management, enlargement of capacity of urban bypasses. Evaluation of road pricing schemes as a possibility.	B ↘
Denmark	One-off traffic congestion study based on traffic counts and local speed-flow functions for cars and buses	Copenhagen: Congestion is considered mild even in peak hours	No information	No information	B
Slovakia (Bratislava, Kosice)	Manual counting, sensors for continuous counting, video surveillance	Insufficient road construction; Congestion limited to peak days and peak times	Congestions will be on increase in large towns due to economic development	Variable road signs, restricted truck access to city centres, Intelligent transport system, electronic tolling	C ↘
Finland (Helsinki)	Travel time system based on number plate recognition, permanent counts, weather system, census, cameras and signal loops	Most congested urban rings and access roads during rush hour; main cause migration and urban sprawl	Continuation of past trend of congestion extension in duration and severity	New capacity / multi level junctions; traffic management services; Improving P.T. and P+R facilities; parking taxation to encourage P. T. use	C ↘
Ireland (Dublin)	Regular monitoring on road users experience; automated traffic counters, visual counts for road monitoring.	Significant fall of journey speed during 2005 and saturation of canal crossing capacity	Until 2008 a drop of journey speeds by 15%, but a recovery until 2016 is predicted	Expand capacities of bus and metro capacities and improved commuter links into and out of Dublin.	C →
Lithuania	No information	No information	No information	No information	
Latvia	No information	No information	No information	No information	
Slovenia	Automatic counting posts; manual counts; micro simulation models	Peak hour congestion at urban arterials and through roads particularly around Ljubljana	Growth, but partial elimination by policy measures	Road investments; ITS systems	B ↘
Estonia (Tallinn)	Manual counting at urban ring and central business district; some automatic counting posts; congestion study; traffic modelling	Most congested important intersections in centre and at city entry; no information on length of peak periods	No information	P. T. priority systems; development of 2 new highways; pedestrian and cycle network development	B
Cyprus	Automatic counts on urban roads; annual census (see inter-urban roads)	Main city corridors are congested	No need to evaluate congestion and delay as described	Currently under evaluation; until now no specific policies in place.	C →
Cyprus	No information	No information	No information	No information	
Luxem-bourg	No specific information; see "inter-urban roads"	Traffic jam at peak hours on main roads access points due to commuter traffic	Luxemburg city +36% traffic increase to 2020; cross-border +3% p.a.	Propote P.T.; reduce commuting by retaining jobs in smaller cities; improve cross-border P.T.	B ↘
Malta (Valetta)	No information	Considerable congestion in Valetta during peak hours	No information	Introduction of cordon pricing; road upgrade programme	C

Table 7-6: Synthesis of country reviews - urban public transport

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
United States	No quantification measures identified.	American transit suffers from congestion largely as a by-product of roadway congestion.	Steady increase as road congestion grows and citizens' first choice remains car purchase	Implementation of reduced stop frequency, traffic signal priority systems, peak-period bus-only lanes	D ↘
Germany	Real-time position data of vehicles feeding into real-time time tables at stops in many cities; no delay data published	Recurring delays of commuter trains sharing track with long distance rail; bus and tram delays no issue	Due to further implementation of operational measures no increase in P. T. delays expected	P. T. acceleration programme; increased investment in track separated tram and light rail systems	B →
France	Real time localisation of bus, tram metro;	Public transport delay is a problem specific to urban agglomeration centres.	No information	No information	C
United Kingdom	Manual counts of bus delays; automated detection of underground and light rail delays	Waiting time for high frequency bus services is continuously decreasing. Stable underground delays	Assumed stable development due to congestion charging zone	Extension of congestion charging zone	B →
Italy	No information	No information	No information	No information	
Spain	No information	No information	No information	No information	
Poland	No information	No information	No information	No information	
Netherlands	No information	No information	No information	No information	
Greece	No information	No information	No information	No information	
Portugal	No information	No information	No information	No information	
Belgium	No information	No information	No information	No information	
Czech Republic	No information	No information	No information	No information	
Hungary	Periodic measures on urban lines, o/d traffic surveys, journey measures of public transport vehicles, ticket and season ticket sales statistics, manual counts	Frequent bus and tram congestion in morning peak. Also congestion at metro due to low density of network and insufficient capacity of old stations.	Stagnation of congestion situation in the longer run resulting from increased demand and improved quality of public transport	Improved data situation by electronic fare collection, New bus, tram and metro lines; new P.T. financing schemes, separation of public and individual road traffic.	D →
Sweden	No information	No information	No information	No information	
Austria	No information	No information	No information	No information	
Switzerland	Delay statistics of urban public transport authorities	Strict priority for P.T. minimises delay risks. Delays relevant for busses using same tracks than private road traffic.	No significant change expected	Improvement of traffic management systems and priority regulation.	B →
Denmark	Recording of bus delays within road congestion study	High punctuality performance	No information	No information	B
Slovakia	Manual data collection since 1975; processing in transport models	Bus and tram delays due to insufficient road construction at peak days and peak times	Problems will become apparent in many towns	Bus and tram line optimisation, new infrastructure, P+R facilities, rapid tram / light rail, integrated transport systems	C ↘
Finland	No information	No information	No information	No information	

Ireland	Recording of journey pattern for selected Quality Bus Corridors.	Significant fall of journey speed during 2005 and saturation of canal crossing capacity	Until 2008 a drop of journey speeds by 15%, but a recovery until 2016 is predicted	Expand capacities of bus and metro capacities and improved commuter links into and out of Dublin.	C ➔
Lithuania	No information	No information	No information	No information	
Latvia	No information	No information	No information	No information	
Slovenia	No information	No information	No information	No information	
Estonia	No information	No information	No information	No information	
Cyprus	The Bus Operators perform daily counts of buses on planned routes	No specific information; as for road sector: congestion on main urban roads	No forecasts carried out so far	Current evaluation by ministry of communication and works and by local bus companies.	C ➔
Luxembourg	No information	No information	No information	No information	
Malta	No information	Public transport by bus suffers the same as road transport from congestion; inter-island P. T. by ferry and helicopter does not experience congestion	No information	No specific programs addressing congestion have been implemented	C

Table 7-7: Synthesis of country reviews - rail

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
United States	Regular recording of AmTrax delays by causes through the Bureau for Transportation Statistics	Freight: Considerable problems due to the lag in grade-separated facilities in the Los Angeles and Chicago regions.	Further increase due to lag of railway companies in funds to finance expensive investments	Investment in grade-separated intersections and truck train interchange facilities by Safetea-Lu	D ↘
Germany	Detailed records of delays by network operator, only publication of actual delays of selected stations on the internet	Punctuality 2004 (2003): 95% (83%). Long term target: 95%. The delay situation is reported differently by different institutions.	Forecasts of rail delays are not available. But the goal of the federal investment plan measures is a substantial capacity extension.	Removal of major bottlenecks; Strategy-Net-21 (separating passenger and freight traffic); technical improvements.	C ↗
France	RFF annual traffic plan; detailed demand and delay database; only for internal use	High speed line Paris – Lyon and other lines and nodes face capacity limits	Additional traffic until 2012 +15% which will increase the saturation	Increased number of slots, additional lines, longer trans, peak load pricing	D ↘
United Kingdom	Regular recording of passenger performance measure and delay minutes by Network Rail	Recovery of punctuality figures after drop in 2001. Overall punctuality 2005: 78%	Growth in employment and road congestion, increased coal imports lead to additional demand.	National Rail Route Utilisation Strategy	C →
Italy	No information	No information	No information	No information	
Spain	No information	Very low; only some dealy exist in some long range lines du to the bad condition of the infrastructure	Due to the strong investments in rail network, it is expected more capacity available	Rail as a political priority concerning transports. Strong investment foreseen until 2020 in high speed rail but also conventional lines	A ↗
Poland	Permanent recording and monthly assessment of delay records; no publication	Utilisation of main lines: 75%, secondary lines: 40%; particular international routes and city agglomerations; Internalisation of delays in time tables; Punctuality: 97%.	A growth in congestion is not expected as traffic is adjusted to time tables; quality of infrastrucutre has a crucial implication	Improvement of infrastructure conditions; defining future financing; increased track access charges for overloaded lines	C →
Netherlands	Analysis of bottlenecks by Prorail (Dutch infrastructure operator)	13 major and 10 minor bottlenecks, of which only the major ones are of sifficient public interest to pay off investment costs	Relief by the opening of the Betouve Lijn (Rotterdam port to Germany) in 2006. Problem: insufficient investments on German part.	ProRail program to boos capacity without on existing network; switch of Voltage to 15 kV AC; gradual introduction of ERMTS and VPT+ systems;	D ↗
Greece	Continuous recording of delays; current preparation of automated electronic delay detection system, Advanced capacity analysis per line.	Most loaded lines from Athens to Chalkida, Thessaloniki, Airport and Korinthos, but no real congestion	Congestion are forecasted to appear in the wider regions of Athens and Thessaloniki.	Improvement of signalisation and the increase of trains' capacity	B ↘
Portugal	The two operators report data in different ways which do not allow comparisons	No publication of quality data by REFER, INTF or CP: CP delay 2005 (3 min. margin): 70% for IC-services	No information	No information	
Belgium	Automated permanent measurement of delays	No congestion problems, no saturated lines. Highest loads on lines reaching Brussels.	Not pertinent for rail; It is essentially the road congestion which evolves.	New high speed lines, realisation of missing links; funding of season tickets for commuters	A →
Czech Republic	Continuous recording of departures and arrivals on main lines	Frequent track closures due to construction works and speed	No specific information. Probably improvement if situation	Network modernisation, in particular four	C

	(5 min. margin). Manual recording for secondary lines	limits. Only small part of lines is most loaded	after network modernisation	transit corridors	→
Hungary	Manual passenger counts, operational traffic controlling programs	Budapest suburban and single track lines. Main reason: old equipment	Expected increase in traffic and rail carriers; further problems at current bottlenecks	Investments in additional tracks, stations and control systems are needed	C ↘
Sweden	Different databases at network operator and carrier; manual encoding of causes	Trains are rather punctual some serious bottlenecks remain	Improvement through investments and regulation measures	Elimination of bottlenecks until 2015; separation of passenger and freight trains, increase of axle loads	B ↗
Austria	Recording of punctuality	Actual study in Austria judges punctuality as good	No information	No information	A
Switzerland	Regular recording and publication of annual punctuality statistics by SBB for passenger and freight services. Monitoring of quality of transalpine combined transport	Delays mainly problem of bottlenecks in Germany and Italy. SBB Cargo punctuality 2002 – 2004: 90% - 92%.	Further improvement due to new railway tunnels	Opening of new NEAT tunnels to relief network from transit traffic	B ↗
Denmark	Continuous recording of delays	Main bottleneck: Railway line between Copenhagen and Ringsted	Improvement through capacity extension	Capacity extension of the railway line between Copenhagen and Ringsted	B ↗
Slovakia	Marketing surveys on service quality, 5 year census,	Numerous delays and train diversions. Sufficient capacity, but standards on quality and reliability are not met	Problems in passenger transport will remain, problems in freight can be solved	Privatisation of rail freight services.	D →
Finland	Continuous recording of delay data by cause and train class. Delay margins: Urban 3 min., inter-urban 5 min.	Punctuality 2005: urban 97,6%, inter-urban 90%. Targets where met. 4 congested track	Elimination of delays through policy measures	Solving of capacity problems through investments and elimination of small delays by time tables	B ↗
Ireland	Railway statistics according to EC regulations	Some capacity saturations, particularly in city centres.	No information	Integrated P. T. network	A ↗
Lithuania	Recording of occasional delays	No regular delays; main delay causes: incidents, natural disasters, track works; technical level below EU standard	Elimination of occasional delays through investment measures	Reconstruction and upgrading of existing rail lines engaged in international carriages	C ↗
Latvia	No specific measurement issues known.	Currently no congestion; some occasional delays due to incidents or track repair; freight delays due to handling problems in ports	Possible future congestion around Riga due to increased passenger demand; main freight corridors, e. g. from and to seaports	Construction of Riga bypass line	A ↘
Slovenia	Continuous real time data collection incl. delays; ticket sales statistics; sample observations	No congestion / delay measures published; problems low infrastructure quality and retaining of trains at border crossings	Partly solving of problems by policy measures	Modernisation of infrastructure; rationalisation of border handling procedures	C ↗
Estonia	No information	No information	No information	No information	
Cyprus	Not applicable	Not applicable	Not applicable	Not applicable	-
Luxembourg	No information	No information	No information	No information	
Malta	Not applicable (no railways)	Not applicable	Not applicable	Railway tunnel from Valetta Grand Harbour to Malta Freeport	-

Table 7-8: Synthesis of country reviews - aviation

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
United States	Delay records collected by Bureau for transportation statistics	Since 1987 no increase in total delayed flights though steady traffic growth; main cause: weather.	Following the past trend average delays will further decrease	No information	B ↗
Germany	Fraport: Collection of delay data but no publication; reporting to Eurocontrol	Currently capacity limits in Frankfurt and close to limits in Munich.	Capacity extension plans will cause considerable over-capacities	Aviation master plan: New runways in Frankfurt and Munich; new Berlin-Berandenburg International airport	C ↗
France	National passenger council (CNCA) has built up a delay observatory covering all flights and affected passengers	Limited infrastructure and airspace capacity	No information, but due to generally very dynamic growth in demand congestion is expected to rise in the future	Use bigger aircrafts; more efficient air space control (stochastic slot allocation; price signals)	D ↘
United Kingdom	No information	No information	No information	No information	
Italy	No information	Largest airports range at lower / middle rank of AEA statistics, slight improvement	No information	No information	C
Spain	No information	Some congestion in the main Spanisg hubs, Madrid and Barcelona, and regional turist aripoorts during summer time	Expected reduction due to large increase in capacity, mainly in Madrid and Barcelona	Generalised investment in the airport system. Strong resources in Barcelona and (above all) in Madrid; important investments in tourist airports	B ↗
Poland	Continuous registration of all activities by radar; reporting to ICAO, Eurocontrol, EU	Rush hours mornings, afternoons and evenings; additional traffic during summer.	Much quicker growth than in rest of Europe	More efficient control systems, reorganisation of airspace; reorganisation of institutions	C ↘↘
Netherlands	No information	Capacity problems to be solved on a European level	No information	Dutch seaports policy until 2010: Document not checked yet.	
Greece (Athens international airport)	Regular reporting of delays and affected passengers to Statistical Agency of Civil Aviation	Athens international airport: insufficient response of air terminals to demand (organisational problem)	No information; due to airport expansion relaxation of situation assumed.	Expansion of Athens international airport; measures to ameliorate quality of service and safety.	C ↗
Portugal	No official method for measuring traffic quality and capacity use	Lisbon airport: Considerable congestion but not yet full capacity utilisation	Capacity limit expected to be reached in 2015	Debate on construction of a new Lisbon airport; not part of national transportation plan	C ↘
Belgium	No information	No information	No information	No information	
Czech Republic	Only passenger flight data recorded; evaluation for peak month (August) to identify capacity needs.	Main bottlenecks have been runway capacity and security check-in at Prague Airport. The problem was solved	Strong growth far above EU average.	Gradual opening of new terminal. Expansion of runway cpacity.	B ↘
Hungary (Budapest Ferrihegi)	Recorded: passengers and landings per day / hour;	Operation close to capacity limit. (no capacity problems at regional airports)	Intensively increasing demand due to low cost airlines; capacity extension urgently needed.	Capacity increase from 12 to 16 million passengers per year; cargo capacity extension	D ↘↘
Sweden	No information	No information	No information	No information	

Austria	No information	Largest airports range at middle level of AEA statistics	No information	No information	C ↘
Switzer-land	Aviation statistics in accordance with EU regulation (Airport and ATM)	Largest airports range at middle level of AEA statistics	Depending on home carrier, in the long run capacity problems	Runway enlargement (long run) planned	C ↘
Denmark	No information	No information	No information	No information	
Slovakia	Volume data is regu-larly observed and published	Congestion happens only in case of extreme weather conditions.	No increase of delays expected	On-going privatisation of Bratislava and Kosice	A →
Finland	No information	No information	No information	No information	
Ireland	Aviation statistics in accordance with EU regulation	No information	No information	No information	
Lithuania	Statistical air traffic counting is an internal matter of airports.	There are presently no congestion problems with any of Lithuania's four airports.	Possibility of conges-tion in Vilnius airport; construction works will force new services devoting to Kaunas.	No information con-cerning future policies	A ↘
Latvia	Main indicators num-ber of passengers and tons of goods.	Currently no conges-tion problems	Problems in Riga airport expected in 2 to 3 years due to economic growth.	Slots regulation; pref-erence to larger air-crafts	A ↘
Slovenia	No information	No information	No information	No information	
Estonia	No information	No information	No information	No information	
Cyprus	The Department of Civil Aviation collects data on a monthly basis in regards to aircraft movements, passengers and freight by airport	Data are examined and emphasis is usu-ally given on peak times such as the holiday season	No information	All the above are currently under evalua-tion by the Depart-ment of Civil Aviation, Ministry of Communi-cations and Works	B
Luxem-bourg	No information	No information	No information	No information	
Malta	No information	There are no conges-tion problems known at Malta airport	No relevant bottle-necks can be identified	No initiatives to in-crease capacity in the near future°..	A →

Table 7-9: Synthesis of country reviews - waterborne transport

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
United States (seaports)	No information	Considerable congstion at Pacific coas ports concerning port capacity and congestion hinterland routes	Further increase due to long investment cycles.	On-going discussion on constructing the Panama Canal and new ports. Problem: Long construction periods	D ↘
Germany (seaports and inland navigation)	Delay statistics, even waiting times at locks, are not recorded.	Congestion is not relevant for inland navigation. Only waiting times at loading facilities; big ships have higher priorities	In the future delays will further decrease as ships get bigger	No actions necessary	A →
France	Satellite data pictures and radar to measure traffic volumes by type of vessel.	Most congested inland terminals (Rheinland, south-west) and seaports (Marseille)	No information	No information	B
United Kingdom	No information	No information	No information	No information	
Italy	No information	No information	No information	No information	
Spain	No information	Some bottlenecks in port access but terminals mostly free of congestion	No major changes expected, only local improvements of acess to land networks	Strong investment policy across the national ports for the period 2007-2013, mainly to increase capacity	B →
Poland	Radars and computer motoring; loading and unloading statistics	No noticed in sea traffic; some problems at locks and opening bridges in inland navigation	Slight increase in seaport utilisation noticed	No information	B ↘
Netherlands		Generally no issue. During July and September waiting times up to 60 h may occur due to reduced staff (holidays.			
Greece	New Vessels Traffic information System: Radio monitoring, meteorological sensors, cameras, etc.	No quantitative delay data. Generally: Each port has certain infrastructure constraints	No forecasts available	No concrete information	B
Portugal	No national official approach	Main bottlenecks related to land access			B
Belgium	No information	As for the Netherlands	No information	No information	
Czech Republic	No information	No information	No information	No information	
Hungary (inland nav.)	Measured are ships per year and day on waterways, tons per year and day in ports	Low utilisation of capacity in waterways and ports; fenny traffic does not hinder river navigation.	No quantitative information, but no significant change expected.	No information. Possibly modernisation of loading facilities to supply environmentally friendly services	A →
Sweden (seaports)	Data from declaration of approaching vessels: AIS-System for automatic location. Mainly for internal use.	Not a problem in maritime shipping. Problem: narrow fairway to Stockholm port. Regular delays in winter, capacity of ice breaking assistance.	The situation is considered not to change.	Use of AIS data for traffic statistics. No specific plans for elimination of narrow spots due to costs involved.	A →
Austria	No information	No information	No information	No information	

Switzer-land	Not relevant	Not relevant	Not relevant	Not relevant	
Denmark	No information	No information	No information	No information	
Slovakia (inland nav.)	Visual observation of traffic volumes and publication by statistical yearbook	Delays only in case of accidents and bad weather conditions. Not relevant	Development or increase of congestion is not supposed	Development of new waterways in eastern Slovakia	A →
Finland (Inland nav. and maritime ports)	Statistics by ship and cargo type retained via national data system PortNet; rea-time vessel tracking system developed	No severe congestion problem; capacity sufficient; but specific needs for certain types of traffic	Forecast until 2030 recently completed. Strong variation and difficult prediction of Russian transit traffic.	No action required. If needed investments in deeper channels will be undertaken.	A →
Ireland	Maritime survey according to EC regulation	No information	No information	No information	
Lithuania (Seaports and Waterways)	No information	Klaipėda seaport recently modernised; no congestion reported; no information in inland waterways	No information	Modernisation of Klaipeda internatinal seaport recently finalised; no information on further plans	A
Latvia	No information	No information	No information	No information	
Slovenia	IT system for volume data collection;	No information	No information	No information	
Estonia	No information	No information	No information	No information	
Cyprus	Data are differentiated by category and port as well as type of cargo handled and passenger data for each port (cruise ships etc).	The CPA and its consultants analyze the data gathered annually with several studies on an as-needed basis in order to identify trends	Congestion in Major ports expected	under evaluation by the Cyprus Ports Authority (CPA)	A ↘
Cyprus	No information	No information	No information	No information	
Luxem-bourg	No information	No information	No information	No information	
Malta		Marsaxlokk (main cargo port): no congestion at the moment.	No current and future bottlenecks can be identified	Inclusion of Malta at the West-Mediterranean Sea Motorway; upgrading of Valetta Grand Harbour; connection to Malta Freeport by rail	A →

7.4 Specific Study on EU and US sea- and airports

Table 7-10: Results for selected EU and US seaports

Country	Measurement and data used	Current state of congestion	Expected development of congestion	Policy plans	LOS slope
US, Pacific and Atlantic coast					
Long Beach (US Pacific)	Some measurement, not structural	Road and rail increasingly congested, terminals equally congested	As traffic increases, problems may worsen	No immediate plans	D ↘
Miami (US Atlantic)	No structural measurement	Problem landside: gate, location close to city	Increasing	Major port redevelopment, new gate system	D ↘
Tacoma (US Atlantic)	Measurement for ships	Strong hinterland congestion	Problems may rise without action	Freight Action Plan, involving all actors	D ↘
Corck (US Atlantic)	Statistical ex-post measurement	Constant inland congestion	Sharp rise	Downstream extensions	C ↘↘
UK Ports					
London (UK, inland seaport)	Every vessel is registered by the Port Authority	No structural congestion on maritime side	Probable worsening on hinterland	No structural plans	B ↘
Humber (UK, east coast)	Time measurement for every vessel	No congestion	No immediate worsening	No plans needed at this stage	A →
Felixstowe (UK, south east coast)	Shipping companies do measurements	No congestion	No worsening expected	No plans	A →
Germany and Benelux, North Atlantic Ports					
Hamburg (Germany, North)	No measurement	Congestion occurs, but not quantified	No worsening	No plans available	B →
Rotterdam (Netherl., Atlantic)	No vessel registration	Only congestion on hinterland side;	Pessimistic	Only Betuwe Lijn to take new traffic to Germany	D ↘↘
Antwerp (Belgium, Atlantic)	Time registration for every vessel	Sometimes congestion, especially at terminals	Situtatiion will improve: new quays, better rail, inland navigation and trucking system	Barge Traffic Services, new rail system, trucking assignment	B ↗↗
Zeebruges (Belgium, Atlantic)	Only ships followed by port; terminal situation assessed by terminal operators	Mainly congestioni in hinterland	No immediate worsening	Port authority has entrance improvement plans and lobbies for better roads	B →

France and Portugal, South Atlantic Ports					
Marseille (France)	For ships: no structural measurement, for hinterland: structural measurement	Only congestion for tankers	Other commodity types may be affected too	Terminal extensions plans	B ➘
Portuguese ports (Atlantic)	No measurements by ports	No congestion	No worsening	No plans	A ➔
Baltic Sea Ports					
Rostock (Germany, Baltic)	No structural meas-urement	Congestion at gates and at terminal; peak congestion in hinter-land transport	Road situation may get worse	Regular checkups with road authorities	C ➘
Aarhus (Denmark, Baltic and North Sea)	Measurement by port and terminals	Minor congestion at terminals	Worsening through overflow from other ports	Terminal extension	B ➘
Kotka (Finland, Baltic))	Data are collected for ships and at terminal	No real congestion	No worsening ex-pected	No plans	B ➔
Rauma (Finland, Baltic)	No structural meas-urement	No recurrent conges-tion	No worsening	No action plans	A ➔
Gdynia (Poland, Baltic)	No structural measur-ment	No congestion, at least not on maritime side	Worsening if no measures	Better hinterland connections	A ➘
Spain and Italy, Mediterranean Sea Ports					
Barcelona (Spain, Med.)	Measurement of time that goods spend in port	Some inland conges-tion	No worsening ex-pected	Discussion groups, no plans yet	B ➔
Genova (Italy, Med.)	No measurement by port authority	Minor congestion in hinterland	No clear view	Planned reinforcing of rail	B ➔

8 Towards a harmonised approach for Europe

Designing an approach for measuring, presenting and assessing congestion requires selection out of a number of methodological options at different levels of the analysis process. These options are:

- Objectives of a congestion monitoring system
- The basic economic and engineering concept of congestion.
- The scope of drivers and effects of congestion
- The geographical scope and time coverage
- The reference travel speed
- Sources and measurement of traffic data
- Values and value transfer for monetary assessment

These items will be covered in the following subsections for road and for scheduled transport. Road is the main focal point of the elaborations. In order to avoid repetitions road covers inter-urban and urban roads and the scheduled transport sections embrace rail and aviation. Waterborne transport is not directly covered as here congestion plays a minor role.

Each section is concluded with a box giving recommendations for a harmonised European approach towards a transport quality monitoring system.

8.1 Objectives of a traffic quality monitoring system

Before defining the detailed methodology of a congestion of traffic quality monitoring system the objectives of the monitoring process must be made explicit. From those objectives the design of indicators can be derived. This step is insofar important as there does not exist a unique definition or measure of congestion; existing measures all have certain strengths and weaknesses in terms of interpretation and they are seldom compatible to each other.

Possible policy objectives towards a congestion or traffic quality monitor are:

- User information on expected traffic quality, conditions and travel alternatives: In this case very regional and intuitive measures, such as service levels, additional travel times or journey time reliabilities are required.
- Tracking traffic condition trends over time to provide an objective basis for the discussion on the necessity of policy interventions. For this purpose congestion or traffic quality measures must be carried out on a regular basis. It is then important that the statistical data base and the applied indicators must be consistent over time.
- Indicating the necessity of investment or traffic management decisions: For this purpose reliable local indicators of congestion or delay costs currently and in case of implementing policy measures are needed. This involves techniques of cost-benefit-analyses and the application of sophisticated traffic forecasting models.

- Ex post assessment of the success of policy interventions: In this case indicators should be sensitive to small changes in traffic quality levels and allow a reliable tracking of congestion trends over time.
- Compliance of current traffic quality with policy targets. Targets may either be formulated by the relative improvement of traffic conditions against a particular base year or as an absolute target value in terms of travel speed, delays or reliability. While in the first case time series are important, in the latter case the indicator system should consist of threshold levels disregarding all traffic operating above policy target.
- Benchmarking between regions: The inter-regional comparison of congestion measures is very problematic due to local network and geographical conditions, traffic management strategies, travel patterns and peoples' attitudes (Doll 2002). For benchmarking reasons the comparison of time series of traffic quality measures gives much more evidence on relative development of regions.
- Assessing the impact of low traffic quality on national accounts, the commercial sector and social welfare: In this case monetary indicators are required which distinguish between business and private transport. Due to the uncertainties involved with congestion cost estimation also in this case comparisons over time are more relevant than absolute values.

We acknowledge all of these rationales behind establishing congestion monitoring systems. But the most relevant from the perspective of European approach are assumed to be the monitoring and benchmarking of congestion trends between regions and over time, the assessment of policy interventions and the verification of policy targets. Therefore, quality indicators must:

1. be transparent, easy to apply and intuitive to interpret
2. Deliver robust and reliable time series
3. Consist of a threshold level for concentrating on real problematic conditions
4. Be sensitive to slight changes in traffic quality below the threshold level
5. Be applicable to all modes. Road traffic quality, delays in rail tansport and air transport are most important.

8.2 The concept of congestion

Congestion may be expressed by one of the four basic concepts:

- Delay-based engineering measures
- Level-of-Service measures
- The Deadweight-Loss approach of welfare economics
- Perceived quality measures

Delay-based or engineering style measures are intuitive, easy to compute, transparent and flexible in terms of adaptation to different local conditions and output needs. With a constant reference travel speed or maximum acceptable delay they allow to keep track of traffic conditions over time. With a careful definition of the reference speeds or delay margins it is possible to verify policy targets, to assess the impacts of policy interventions or even to approach the economic costs of congestion to society and / or to the commercial sector. However, a sound computation of the economic costs of traffic congestion is not possible with delay-based indicators, unless the reference speed exactly reflects the congestion level where costs of the site-specific least cost measure of congestion relief just equals the achieved benefit by that measure. This would imply that first, the definition of the reference speeds gets rather complex and second that they would considerably vary from location to location. Differing reference conditions could further rise equity concerns, the resulting congestion measure would not express traffic conditions but “shadow costs of policy interventions” and consequently the interpretation of time series of congestion indicators would get rather difficult.

The LOS-concept is related to delay indicators through the definition of the LOS-boundaries. Transportation planners are used to the concept and it provides an intuitive standard for labelling and visualising traffic conditions. However, there is growing criticism against the concept because it is rigid to local problem perceptions, changing traffic conditions within a particular LOS-grade are disregarded, the definition of the upper and lower speed boundyry of each grade appears arbitrary and their ranges of travel speeds defining each LOS-grade are too different. Consequently, the LOS-concept is not suitable for tracking traffic quality trends over time.

The deadweight loss measure is best suitable for pre-assessing the potential economic benefits from demand-related policy measures, in particular of marginal cost based transport pricing. However, measuring total congestion costs by the dealweight-loss concept gets rather difficult in terms of computation, the concept is not very intuitive and it does not directly express traffic quality standards. Further it can not be applied to scheduled transport as here congestion effects are already internalised by the network operators calculus whether to provide tracks or slots to service operators. Thus the concept is not suitable for inter-modal comparisons.

Finally, the assessment of users’ perception of traffic quality can be a valuable indicator to adopt numerical traffic quality measures to local conditions. For instance they can be applied to generate location-specific reference travel speeds for road congestion assessment. The establishment of perceived quality measures appears relatively cheap, but they are based on current user attitudes and thus do not allow to keep track of quality evolutions over time.

Table 8-1 provides an overview of the methods and their strengths and weaknesses according to several policy goals.

Table 8-1: Comparison of congestion estimation methods.

Cause	DWL	ACA	PQA
Data requirement	high: supply and demand functions	medium: delays or supply and demand data	low: conduction of interviews
Modelling capacity needs	high: network-based equilibrium models	low to medium: observations or standard network models	none
Transparency	low	high	high
Indication of potential benefits through			
demand management	highly appropriate	less appropriate	less appropriate
Investment measures	not appropriate	highly appropriate	appropriate

Reflecting on the pros and cons of the four concepts for reasons of robustness, transparency and suitability for tracking transport quality trends over time the delay-based approaches are recommended for application to all modes within a harmonised European monitoring system. This position is underlined by the methodologies applied by most of the congestion studies in Europe, the US and Canada. Nevertheless, the LOS-concept may be applied to categorise and visualise congestion levels.

8.3 Scope of drivers and impacts of congestion

Congestion and delays may have various reasons:

- bottlenecks and capacity shortage at links or nodes,
- the physical condition and quality of infrastructures and vehicles,
- infrastructure construction activities,
- accidents,
- weather conditions,
- operation and management failures,
- technical problems with infrastructures or vehicles,
- sundry other reasons.

In many cases delays appear as the result of multiple reasons. However, a detailed analysis is difficult becuase the available statistical data does not provide insight into the main causes for all modes. Nevertheless, the study aims to focus on delays due to the capacity and quality of infrastructures.

In particular in rail and air services, but also in non-scheduled transport, reactionary delays following an event at a particular location and affecting wider network parts play an important role. Even though the primary cause of the delay may not be capacity-related, it can be argued that the configuration of the capacity margins do not suffice to compensate for this single event and thus the question of capacity becomes relevant in the second instance.

Another methodological problem is the increase in travel time due to the anticipated regular occurrence of delay causes. These "hidden delays" constitute a particular problem in rail transport, where timetables are adapted to increasing travel times due to declining network quality levels. The introduction of the Passenger Rights Charta in the European rail market has increased this trend, in order to protect the railways from excessive compensation payments. Although the consideration of these extra travel times could shed some more light on the real condition of railway infrastructures and the lag in maintenance measures, the quantification is considered rather speculative and will thus be excluded from the analyses within the COMPETE project.

Table 8-2 provides an overview of the scope of congestion or – more precisely – of capacity-related delays within the subsequent analyses.

Table 8-2: Causes and scope of congestion

Cause	Description	Treatment	Modes
Capacity	Traffic jams or late arrivals due to lacking infrastructure capacity.	Main focus	All
Network quality	Reduced speed / late arrivals due to insufficient physical quality of the infrastructures.	Included	All
Construction activities	Traffic jams / delays due to construction sites at infrastructures.	Not included	All
Accidents	Traffic jams / delays following traffic accidents.		All
Weather	Influence of (expected and unexpected) weather activities on travel speeds and arrival times.	Not included	All
Operation	Managerial or operational failures, personnel problems at transport service providers.	Not included	Scheduled
Technical problems	Reduced speeds / detours / late arrivals due to technical problems at infrastructures or vehicles.	Not included	Scheduled
Reactionary delays	Secondary delays caused by an event in other parts of the network.	Included	Scheduled
Sabotage	Traffic jams / delays due to vandalism or terrorist attacks on infrastructures or vehicles.	Not included	Rather scheduled
Suicides	Traffic jams / delays following suicides or similar.	Not included	Mostly rail
Hidden delays	Adaption of timetables to frequent delays.	Not included	Mainly rail

8.3.1 Road transport

In the narrow sense congestion denotes the disturbance of traffic conditions as demand approaches infrastructure capacity. However, it is not only excessive demand, but also other factors such as accidents, technical problems, bad weather conditions or insufficient infrastructure quality which increase travel time and decrease journey time reliability. Often, the multiple purposes can not be separated. This holds in particular for scheduled transport, where incidents at one part of the network affect distant locations.

To separate pure capacity-driven congestion from all-purpose distortions the following concepts have been defined:

- Recurrent congestion denotes the decrease in road service quality when actual demand exceeds infrastructure capacity. Sporadic distortions, such as accidents, suicides on rail lines, problematic weather conditions, technical problems or other are excluded.
- Non-recurring congestion measures include all purposes and thus provide a measure of traffic quality rather than of congestion in the narrow sense.

For policy purposes both concepts can be meaningful. While measures of recurrent congestion indicate the need for capacity extension or traffic demand management, non-recurrent congestion keeps track of the overall quality of the transport system. The following table contains information provided by interview partners or studies reviewed on the several purposes of congestion and delays in different modes.

Table 8-3: Reasons of congestion according to multiple studies

Mode	Study, area	Congestion / delay cause				
		Capacity	Construction works	Accidents	Weather	Operators / Other
Road	TTI Urban Mobility Rep.	30 %-60 %		40 %-70 %		
	CEDR (2005) [1]:	40%	41 %	18 %	9 %	9 %
	Hessen, Germany	30 %	30 %	10 %	30%	
	France, Ile de France	85 %	4 %	11 %		
	Netherlands	82 %	5 %	13 %		
Rail	UK Network Rail	32 % [1]	44 % [1]		10 %	14 %
	Sweden, Bahnverket	36 %	5 %			59 %
Air	US, DOT	36 %			4 %	60 % [3]
	Europe, AEA	30 %			4 %	66 % [3]
	Europe, Eurocontrol [2]	11 %	-	-	11 %	78 % [3]

1) Number of cases; 2) ATFM En-Route delays; 3) Airlines: 51%, Airport: 19%, security: 4%, miscellaneous: 4%, 3) network management, 4) asset defects,

In road transport, the determination of recurrent congestion is straight forward as here engineering speed-flow functions can be used to transform traffic counts into vehicle speeds. Moreover, the reporting system gets much simpler in case only capacity-related effects need to be taken into account. In the case of monitoring non-recurring congestion information on delay causes are decisive in order to be able to draw meaningful policy conclusions. This makes the reporting system more complicated and due to the sporadic occurrence of particular delay causes a steady monitoring of traffic over time is required. Alternatively, average rates for non-recurring congestion according to Schrank and Lomax (2005) for US cities could be applied, but the underlying factors require a frequent update in order to reflect the impacts of policy interventions or changes in peoples' behaviour adequately.

Non-recurring congestion can be measured by floating car and mobile transmission data, but difficulties arise in separating the various delay causes. In some cases, in particular in air or rail transport, this is even theoretically impossible due to chains of causes across networks. Alternatively, incident and congestion statistics by network operators or by radio messages can be used.

Apart from the causes, the impacts of congestion to be monitored need to be selected. Besides time losses, congestion causes increased fuel consumption and additional atmospheric emissions. Wasted fuel and additional pollutants can be quantified via speed-dependent consumption and emission functions. For time, fuel and atmospheric emissions a variety of unit cost estimates or consumer prices exist, which can be applied to express congestion effects in monetary terms.

For the initial phase of a harmonised European approach we propose to establish travel-time related indicators of recurrent congestion as the basic measure. Advanced applications then would add measures of non-recurrent congestion by numbers of events, cause, wasted fuel and excessive environmental effects and / or the monetary assessment of these effects.

8.3.2 Scheduled transport

In rail and air transport the situation is somewhat clearer than in road as on the one hand pure capacity related delays constitute the minority and the network and service operators in both modes keep records of delays by severity and cause.

As concerns the effects of delays and capacity shortages additional time costs of passengers, vehicle operating and staffing and fuel costs of the service providers and additional air emissions occur. The determination of additional operating and emission costs in air and rail transport is not as straight forward to compute as in road as here simple speed-flow-curves do not apply. But the respective numbers are kept by the operators.

In scheduled transport non-recurrent congestion measured in delay time for passengers and cargo by type of cause are proposed for a harmonised approach. In a later phase additional operating cists, fuel consumption and air emissions may be added.

8.4 Geographical Scope and time coverage

8.4.1 Road transport

Road congestion assessment may focus on a selected set of links (DfT 2000), estimate total network effects by single link measurements (Scottish Executive) or measure congestion on entire networks as in the case of German motorways (IVV 2004) or the Copenhagen road network (Hvid 2004). In order to obtain stable time series of congestion the set of road links monitored must not change significantly between the periods of measurement. Extrapolating single link measurements to wider network parts, which reduces the sensitivity of results with respect to the selection of monitoring spots, bears the risk of not adequately tracking shifts between network parts over time.

As concerns urban areas the UNITE project (Doll 2002) has found that a transfer of congestion results between urban areas is not possible. Thus the country-wide extrapolation of results for a sample of urban areas is not an option.

Traffic quality may be measured continuously over the whole year or be performed at selected time periods only. In case of computing trip- or kilometre-specific indicators of recurrent congestion, such as the relative increase in journey time due to congestion, one-time measurements are totally sufficient. in case annual values are to be produced, continuous measurements or an extrapolation is required. Determining non-recurring congestion eventually demands for a measurement over a longer period of time.

For the measurement of inter-urban road congestion it is recommended to start with a sample of corridors on the TEN, where the link segments to be included should be proposed by the member states. As concerns urban transport the monitoring system should start with a limited number of cities which are willing and technically equipped to perform congestion measurements. Within each city urban expressways and arterials and a set of urban collectors, which are to be identified by local authorities, should be considered. Both, cities and countries, may of course extend the measurement to the secondary network, the results should, however, be treated as additional information.

8.4.2 Scheduled transport

IN rail transport delay statistics normally cover the entire network across an entire year. But the figures are commonly not weighted by the number of passengers affected or they give just the arrival delays of trains at their final destination regardless of delays at intermediate stations. Further, none of the delay statistics take account of missed connections. However, this type of inconvenience affects many passengers much more than the sole delay of single trains.

In air transport the data situation is far better as here arrival and departure delay statistics by airports or flight regions and by flight times in a harmonised European standard exist. But the problem of missed connections is also not treated by aviation statistics.

The problem of missed connections also gets relevant in intermodal transport chains involving changes from road, rail or air to a scheduled mode.

For a harmonised approach we propose the following procedures for rail and air transport

- In a first step train delays at selected European stations and the respective number of passenger debarking should be monitored across all day periods. In aviation Eurocontrol statistics on flight regions should be made available by single airports. In case an all-year measurement is not possible several representative weeks over the year should be chosen.
- In a second step a selected number of trips involving train changes in the case of rail transport or transfers at airports in the case of aviation should be observed

8.5 Congestion indicators

The basic indicators can be characterised as follows:

- Travel speed is the most straight-forward indicator for the development of traffic conditions on a local level. It might either be determined by direct speed measurement, by applying speed-flow diagrams to flow measurement or by a combination of both. Speed-based indicators allow keeping track of congestion over time but benchmarking different areas gets difficult.
- Time losses are derived from speed indicators by comparing actual to reference travel speeds on a local level. If computed for a larger area time losses need to capture network parts for which flow or speed measurements are not available. Thus the application of traffic models consisting of well-defined speed-flow diagrams (SFD) is required. Average time losses, which are computed by dividing the sum of all time losses by all trips, passenger- or vehicle kilometres may be used to benchmark areas or to monitor traffic over time in case the computation methods are compatible.
- Additional time costs: Travel time losses may be assessed by a value of travel time, which ideally should distinguish between travel purposes. This requires split of the traffic flow between the congestion experienced by commercial transport and by private, commuting and leisure trips, as only time costs of commercial transport are fully GDP-relevant. Without this separation the comparison of total congestion costs to GDP can only serve to judge the magnitude of results rather than to adjust GDP estimates.
- Additional fuel, operating and emission-related costs can be derived out of travel speeds using vehicle fuel consumption functions. Usually they range in the order of 10% of time costs only. From the fuel consumption other measures, such as air and greenhouse gas emissions can be derived.

All of these indicators require the derivation of travel speeds out of traffic volume measurements. Establishing such a system might require substantial time and resources. A simpler approach is the evaluation of records of traffic congestion messages, which are provided via the Traffic Message Channel (TMC) in most countries. However, the quality of the messages varies substantially across the countries. An initial indicator of traffic quality could be the number of messages by congestion cause, related to a certain base year. Traffic message related indicators are in particular suitable for the motorway network.

A harmonised European approach of monitoring congestion can only be initiated with a very simple set of indicators which allow the dynamic tracking of the evolution of transport quality. The establishment of robust time series for selected cities and critical parts of the TEN-networks should be the EC's first priority. Therefore the following indicators are proposed:

- □ Average time loss per passenger kilometre: basic indicators for further derivations
- □ Average increase in journey time for a more understandable user information
- □ Total time loss for comparison to operating cost or, GDP or other macro-economic indicators
- Relative increase in traffic messages by severity and cause against a base year

In the ideal case the indicators can be diversified by type of infrastructure (motorways, urban expressways, arterials, etc.), by passenger and freight vehicles and by time segment (peak, off-peak). Further they should be expressed as recurrent and non-recurring congestion. This can be done by analysing the reasons of congestion events, based on infrastructure operators' statistics.

In a later stage or for more advanced regions monetary costs, fuel consumption or environmental effects may be added.

8.6 The reference travel speed

8.6.1 Road Transport

For speed or delay-based indicators the selection of the reference level of traffic quality constitutes the main determinant of congestion. Most studies reviewed take the free-flow speed to compute time losses. Free flow speeds might either be measured by floating car vehicles in off-peak periods or may be set according to the speed limits by road type.

As infrastructures are built to carry a certain traffic load which involves a certain level of mutual interference of traffic users, free flow conditions are certainly not an appropriate benchmark to quantify congestion, since congestion being a relevant economic issue would be overestimated. However, free flow conditions are easy to determine and remain stable over time. Furthermore, when monitoring the development of traffic conditions over time or between regions the absolute reference level of traffic conditions is not relevant.

In case congestion measures are to indicate investment needs, the reference speed should correspond to the traffic level where the costs and benefits of capacity expansion just balance out. As construction costs are particularly varying by the degree of urbanisation, reference levels then would be different from region to region.

In case congestion is intended to express the costs of dense traffic conditions to society, the reference speed needs to be based on acceptability studies. Simplified approaches use a certain percentile, e. g. the Median as the 50% percentile of travel speeds measured during an ordinary working day. This, however, implies that the reference speed strongly depends on the share of traffic suffering from congested conditions and is thus not suitable for benchmarking or tracking traffic conditions over time.

Finally, when the fulfilment of policy targets is to be monitored these targets need to be transformed into reference speeds or maximum delays. Commonly, policy targets are expressed by a certain percentage of permitted or design speed. For example Transport Canada (TC 2006) applies a threshold of 60% of actual speed limits and the German motorway bottleneck analysis (IVV 2004) takes a fixed speed of 75 kph, which is 58% of the design speed. It is important to constitute that these are simple but arbitrary.

For a harmonised European approach towards the monitoring of congestion the reference level should be simple to determine, remain stable over time and indicate the violation or the fulfilment of policy targets. We thus propose to apply the Canadian and the German approach by defining the reference speed at some 60% of actual speed limits of the roads design speed or speed limit. The choice of threshold is somewhat subjective, because it must take into account local perceptions of congestion, but it is believed to give a more sustainable target for congestion reduction than free flow (TC 2006).

8.6.2 Scheduled transport

In scheduled transport time table information provides a natural reference point for delay determination. Compared to free flow speed on roads, this is, however, not good basis for delay measurement. Delay margins in practice vary between modes (rail smaller than air) and transport sector (passenger shorter than freight).

For a European monitoring system we propose the following delay margins:

- Rail passenger: 5 minutes
- High quality rail freight: 30 minutes
- Air passenger 15 minutes
- Air freight: 30 minutes

8.7 Data Sources and measurement of traffic data

8.7.1 Road transport

Speed measurements in road transport may either be taken by detector systems (induction loops, speed cameras, radar systems) or by floating cars. Induction loop measurements have the advantage to deliver speed and traffic volume data consistently, while floating cars may cover a wider network part without having to install expensive road-side facilities. In case recurrent congestion is measured by a one-time snapshot-study the time of measurement should be in a period not affected by major holidays and extreme weather conditions,. Recommended are November and March (Infras 2004, DfT 2000)

Speed-flow diagrams are required to compute recurrent congestion from traffic volume data. The choices are between using pre-defined speed-flow curves versus the estimation of site-specific functions from recorded volume and speed data. Speed-flow relations are not transferable However, the estimation of site-specific speed-flow curves may be too resource consuming for an European approach.

Examples may be the revised speed-flow curves for motorways, trunk roads, urban collectors and city streets by number of lanes as proposed for German traffic planning by FGSV (1997) or the Speed-flow curves of the UK COBA-Manual for Cost-Benefit Analyses (e. g. DETR 1998) presented by Figure 8-1 and Table 8-4).

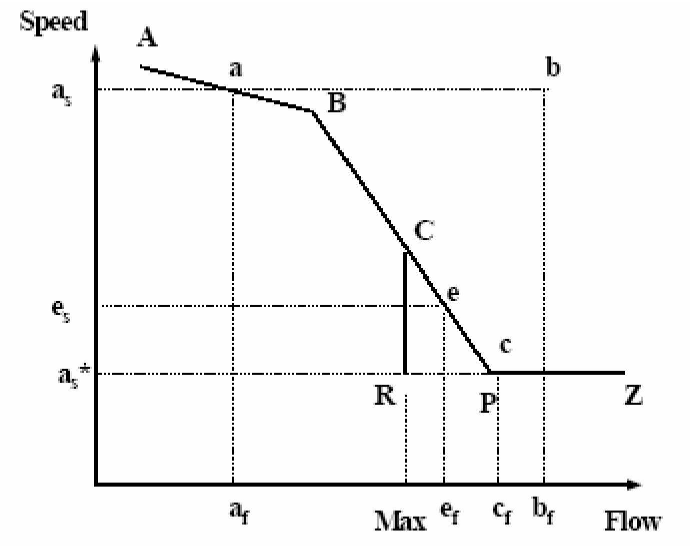

Figure 8-1: Principal slope of the UK speed-flow curves

Table 8-4: Parameters for UK speed flow functions

Points on S/F curve	Motorways Flow	Motorways Kph	T & P Dual Flow	T & P Dual Kph	T & P Single Flow	T & P Single Kph	B roads Flow	B roads Kph	C & Unc-liassified Flow	C & Unc-liassified Kph
A	0	114	0	103	0	86	0	70	0	70
B	1200	107	1,050	96	1,000	72	880	52	800	55
C	2000	80	1,750	70	1,300	57	1,100	40	1,000	43
R	2000	40	1,750	40	1,300	40	1,100	40	1,000	40
P	3185	40	2,558	40	1,640	40	1,100	40	1,050	40

Source: DETR (1998)

For practical applications the German functions are recommended as their non-linear definition seems to fit actual traffic conditions better and because they take account of curvature, grades and HGV shares. A general comparison between the two types of curves is presented by Figure 8-2 taken out of Maibach et al. (2004).

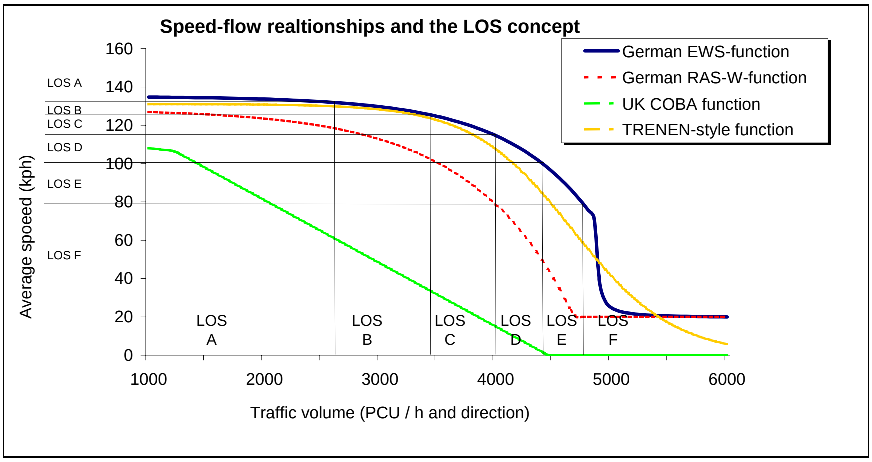

Figure 8-2: Travel speed and Level of Service for passenger cars on a three lane motor-way using different speed-flow curves

Another source of data is radio messages for congestion events. Traffic messages of inter-regional importance are broadcasted via the free of charge Traffic Message Channel (TMC) in most European countries and the US. Although TMC consists of standard code lists for events and locations, the quality of the messages is extremely divergent between countries. However, for a European congestion monitoring system an extension to all member states and a unique quality of the messages should be approached.

In case congestion measures are based on traffic density data the estimation of location-specific speed-flow functions is recommended. If this is not possible the application of the functions proposed for German traffic planning or other standard curves are proposed as a starting point to transform traffic flow data into travel speeds.

As a first step towards a common European road quality monitoring system the EC should foster the development of a European traffic data management centre, which should ensure a unique quality and the regular evaluation of traffic messages across the EU.

8.7.2 Scheduled transport

In rail and air transport the infrastructure operators and service providers usually consist of excellent delay monitoring systems. In rail transport the data is, however, usually confidential (private). Only aggregated figures are published, which are not suitable to monitor traffic quality.

In urban public transport delay statistics are hardly available at all. Due to the usually high degree of subsidies received by this sector some kind of public quality monitoring would, however, be sensible.

In air transport the situation is much better as Eurocontrol's Central Office for Delay Analyses (CODA) collects and processes the delay reports for flight regions. Delay data by airports for most European airlines is published by the Association of European AirlinesConsumer Reports (AEA 2005). However, as mentioned before, neither in air nor in rail transport data on missed connections due to delays is available.

For a harmonised European approach of high quality congestion monitoring it is thus recommended to oblige the railway sector to publish punctuality statistics by train class and delay purpose on a regular basis.

This is furthermore necessary for (subsidized) public transport, especially in urban areas.

In aviation Eurocontrol delay statistics should be made available at least for a sample of distinct airports.

8.8 Values and value transfer for monetary assessment

Expressing extra time consumption, fuel wasted or environmental effects caused by congestion in monetary terms can be useful to set congestion in relation to macro-economic indicators (e. g. GDP) or to judge its relevance for business and industry cost structures (see chapter 4). For translating time losses into money units co-called "values of travel time" are required. They might be determined by observations of users' behaviour (revealed preferences) or by interviewing them (stated preferences). Both variants consist of pros and cons. Surveys on the results of value of time studies suggest that different values apply to normal travel time (in-vehicle time), wait time and driving time under congested conditions. Wait and congested time should value around 50% higher than uncongested in-vehicle time. The values further differ by travel purpose (business, commuting and leisure, freight commodity), by travel distance and by mode. A compilation of results has been presented by the UNITE project (Link et al. 2002)

Table 8-5: Parameters for congestion assessment by market segments

Transport segment	Value of travel time (Link et al. (2000) for EU 1998)	Typical reference speeds (Vref) or delay margins (Dmax)
Passenger transport		
Car / motorcycle		Motorways Vref = 90-110 kmph, ??
Business	21.00 €/pass.-h	trunk roads Vref = 40-60 kph
Commuting / private	6.00 €/pass.-h	urban roads: Vref = 15-25 kph
leisure / holiday	4.00 €/pass.-h	
Coach (inter-urban)		
Business	21.00 €/pass.-h	Motorways Vref = 70-80 kph,
Commuting / private	6.00 €/pass.-h	trunk roads Vref = 40-50 kph
leisure / holiday	4.00 €/pass.-h	
Urban bus / tramway		
Business	21.00 €/pass.-h	Including stops at stations: Vref = 10-20 kph
Commuting / private	6.00 €/pass.-h	excluding stops at stations: Vref = 10-15 kph
leisure / holiday	3.20 €/pass.-h	
Inter-urban rail		
Business	16.00 €/pass.-h	Long-distance transport: Dmax = 5 min.,
Commuting / private	6.40 €/pass.-h	local transport Dmax = 2-3 min.
leisure / holiday	4.70 €/pass.-h	
Air traffic		
Business	16.20 €/pass.-h	Usually Dmax = 15 min.
Commuting / private	10.00 €/pass.-h	Heavy delays: Dmax = 60 min.
leisure / holiday	10.00 €/pass.-h	
Freight transport		
Road transport	32.60 €/veh.-h	Motorways: Vref = 60-80 kph,
LDV	40.76 €/veh.-h	Trunk roads Vref = 40-60 kph
HDV	43.47 €/veh.-h	Urban roads Vref = 15-25 kph
Rail transport		
Full trainload	725.45 €/train-h	High quality services: Dmax = 15-30 min.
Wagon load	28.98 €/wagon-h	Common services: Dmax = 30-60 min.
Average per ton	0.76 €/t-h	
Inland navigation		
Full ship load	201.06 €/veh.-h	No information
Average per ton	0.18 €/t-h	
Maritime shipping		
Full ship load	201.06 €/veh.h	No information
Average per ton	0.18 €/t-h	

The specific values for delay margins and the VOT per mode, travel purpose or market segment will be finally decided on when the various national procedures of the EU Member States, Switzerland and the United States have been reviewed.

The UK DfT applies an average value of 10 Euros per person hour and the The values might be transferred between countries by GDP per capita and may be updated over time by inflation rates. However, local and contemporary estimates should be used where available.

Fuel prices are available by national statistics. Operating costs should be made available from company statistics and industry associations. Common values for the EU can hardly be recommended. Money values of air and greenhouse gas emissions are available from several sources (UNITE D7, Maibach et al. 2004).

8.9 Conclusions and implementation

On the basis of the studies reviewed in particular when looking to North American practice the following recommendations for a harmonised approach for Europe emerge:

- It should be initiated by monitoring a sample of sections of the TEN-T road network and selected cities in each member state, including the capitals and a number of smaller cities in the large countries. Delay-based indicators should be applied due to their transparency.
- The delay monitoring must be dynamic by providing robust time series and it must reflect the compliance of current traffic quality with policy targets. Therefore the reference travel speed in road transport or the delay margin in air traffic must be fix over time. For road 60% of free flow or maximum permitted speed are recommended. In rail passenger 5 minutes and in high quality rail freight and in aviation 30 minutes delay margin are recommended. However, local derivations are possible.
- In first instance recurrent congestion on a selected day in the year should be monitored in road transport. In a later stage all delay purposes should be added by establishing a continuous monitoring scheme. In scheduled transport all delay purposes by delay cause are to be included.
- Data sources in road transport are speed and flow measurements by automatic counting posts (UN, national or local) or floating car vehicles. Speed-flow diagrams should be estimated case by case to capture local conditions. If this is not possible standard speed-flow curves, e. g. the German EWS-functions, may be applied.
- Further it is recommended to establish a European road traffic control centre harmonising and assessing traffic messages. As a very first step towards a European monitoring system for traffic conditions the number of traffic messages can be evaluated by severity and cause towards an initial traffic quality indicator. This approach is in particular suitable for motorways.
- For rail transport it is recommended to enforce railway companies to present detailed annual delay statistics, comparable to the Eurocontrol analyses in air transport.

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Appendix A: Speed-Flow Functions

1 EWS Road Types

Type	*Description*
1	**Grade-separated carriageways outside built-up Areas**
1.11	Ramps of single-level intersections (1 carriageway)
1.21	2 Carriageways, with emergency lane
1.22	2 Carriageways, without emergency lane
1.31	3 Carriageways, with emergency lane
1.32	3 Carriageways, without emergency lane
1.41	4 Carriageways, with emergency lane
1.42	4 Carriageways, without emergency lane
2	**Other rural roads**
2.11	1 Carriageway per direction, carriageway width above 10 m, single-or multi-level
2.12	1 Carriageway per direction, carriageway width 7 - 10 m, single-or multi-level
2.13	1 Carriageway per direction, carriageway width below 7 m, single-or multi-level
2.21	2 Carriageway per direction, double carriageways, single-level
2.22	2 Carriageway per direction, single carriageways, single-level
2.31	3 Carriageway per direction, double carriageways, single-level
2.32	3 Carriageway per direction, single carriageways, single-level
3	**Grade-separated carriageways within built-up areas (Urban highway)**
3.11	Ramp of multi-level intersections (1 Carriageways)
3.21	2 Carriageway per direction, with emergency lane
3.22	2 Carriageway per direction, without emergency lane
3.31	3 Carriageway per direction, with emergency lane
3.32	3 Carriageway per direction, without emergency lane
3.41	4 Carriageway per direction, with emergency lane
3.42	4 Carriageway per direction, without emergency lane
4	**Prioritised urban roads <u>without</u> obstacles**
.411	1 Carriageway per direction, outside residential areas (Vmax > 50 km/h)
4.12	1 Carriageway per direction, within residential areas
4.21	2 Carriageway per direction, double carriageways
4.22	2 Carriageway per direction, single carriageways
4.31	3 Carriageway per direction, double carriageways
4.32	3 Carriageway per direction, single carriageways
4.41	4 Carriageway per direction, double carriageways
4.42	4 Carriageway per direction, single carriageways
5	**Prioritised urban roads with obstacles (by influence of intersections, standing traffic or public transport)**
5.11	1 Carriageway per direction, open, multi-sorey building development
5.12	1 Carriageway per direction, closed building development
5.13	1 Carriageway per direction, commercial road
5.21	2 Carriageway per direction, double carriageways
5.22	2 Carriageway per direction, single carriageways
5.31	3 Carriageway per direction, double carriageways
5.32	3 Carriageway per direction, single carriageways
5.41	4 Carriageway per direction, double carriageways
5.42	4 Carriageway per direction, single carriageways
6	**Urban road with obstacles by missing priority and standing traffic / residential-, access road**
6.01	traffic-calmed road with open building development
6.02	Traffic calmed road with closed building development
6.11	Residential road, open building development
6.12	Residential road, closed building development

2 EWS Speed-Flow Functions

TableAnnex 1: Speed functions for vehicle group P (passenger cars) on trunk roads

ST	V_P [km/h]	Range of traffic volume (veh./h per direction) Empirical evidence	Transition at s=0, ku=0	Congestion
1.11,	$V_P = 208{,}5 - 105 \cdot \cosh\left(\frac{s+1}{10}\right) + 2 \cdot \left(1 - \exp\left(1{,}59 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)\right)$	≤1.800		
3.11	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 1.780{,}88\right) \cdot 10^{-3}\right) + 17{,}71$		>1.800	
	$V_P = 20$			>2.250
1.21, 1.22,	$V_P = 138{,}6 - 8 \cdot \exp(0{,}235 \cdot s) - 0{,}1 \cdot \exp\left(1{,}643 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)$	≤3.900		
3.21, 3.22	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 3.880{,}52\right) \cdot 10^{-3}\right) + 18{,}86$		>3.900	
	$V_P = 20$			>4.875
1.31, 1.32,	$V_P = 143{,}1 - 8 \cdot \exp(0{,}235 \cdot s) - 0{,}1 \cdot \exp\left(1{,}157 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)$	≤5.600		
3.31, 3.32	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 5.580{,}44\right) \cdot 10^{-3}\right) + 18{,}88$		>5.600	
	$V_P = 20$			>7.000
1.41, 1.42,	$V_P = 145{,}1 - 8 \cdot \exp(0{,}235 \cdot s) - 0{,}1 \cdot \exp\left(8{,}68 \cdot 10^{-4} \cdot (Q_P + 2 \cdot Q_{GV})\right)$	≤7.500		
3.41, 3.42	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 7.480{,}41\right) \cdot 10^{-3}\right) + 18{,}95$		>7.500	
	$V_P = 20$			>9.375
2.10	$V_P = \left(215{,}5 - 105 \cdot \cosh\left(\frac{s+1}{10}\right)\right) \cdot \exp(-10^{-3} \cdot KU) + 0{,}1 \cdot \left(1 - \exp\left(3{,}272 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)\right)$	≤1.900		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 1.880{,}84\right) \cdot 10^{-3}\right) + 7{,}81$		>1.900	
	$V_P = 10$			>2.375

ST	V_P [km/h]	Range of traffic volume (veh./h per direction) Empirical evidence	Transition at s=0, ku=0	Congestion
2.11	$V_P = \left(208{,}5 - 105 \cdot \cosh\left(\frac{s+1}{10}\right)\right) \cdot \exp(-10^{-3} \cdot KU) + 0{,}1 \cdot \left(1 - \exp\left(3{,}37 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)\right)$	≤1.800		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 1.780{,}88\right) \cdot 10^{-3}\right) + 7{,}71$		>1.800	
	$V_P = 10$			>2.250
2.12	$V_P = \left(202 - 105 \cdot \cosh\left(\frac{s+1}{10}\right)\right) \cdot \exp(-10^{-3} \cdot KU) + 0{,}1 \cdot \left(1 - \exp\left(3{,}472 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)\right)$	≤1.700		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 1.680{,}92\right) \cdot 10^{-3}\right) + 7{,}6$		>1.700	
	$V_P = 10$			>2.125
2.13	$V_P = \left(195{,}5 - 105 \cdot \cosh\left(\frac{s+1}{10}\right)\right) \cdot \exp(-10^{-3} \cdot KU) + 0{,}1 \cdot \left(1 - \exp\left(3{,}746 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)\right)$	≤1.600		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 1.576{,}47\right) \cdot 10^{-3}\right) + 7{,}5$		>1.600	
	$V_P = 10$			>2.000
2.14	$V_P = \left(188{,}5 - 105 \cdot \cosh\left(\frac{s+1}{10}\right)\right) \cdot \exp(-10^{-3} \cdot KU) + 0{,}1 \cdot \left(1 - \exp\left(4{,}666 \cdot 10^{-3} \cdot (Q_P + 2 \cdot Q_{GV})\right)\right)$	≤1.300		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 1.269{,}63\right) \cdot 10^{-3}\right) + 7{,}07$		>1.300	
	$V_P = 10$			>1.625
2.21, 2.22	$V_P = 118 - 8 \cdot \exp(0{,}235 \cdot s) - 5 \cdot \exp\left(6{,}58 \cdot 10^{-4} \cdot (Q_P + 2 \cdot Q_{GV})\right)$	≤3.500		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 3.480{,}55\right) \cdot 10^{-3}\right) + 8{,}6$		>3.500	
	$V_P = 10$			>4.375

ST	V_P [km/h]	Range of traffic volume (veh./h per direction) Empirical evidence	Transition at s=0, ku=0	Congestion
2.31, 2.32	$V_P = 118 - 8 \cdot \exp(0{,}235 \cdot s) - 5 \cdot \exp\left(4{,}26 \cdot 10^{-4} \cdot (Q_P + 2 \cdot Q_{GV})\right)$	≤5.400		
	$V_P = \coth\left(\left((Q_P + 2 \cdot Q_{GV}) - 5.380{,}45\right) \cdot 10^{-3}\right) + 8{,}86$		>5.400	
	$V_P = 10$			>6.750

TableAnnex 2: Speed functions for vehicle group GV (goods vehicles) on trunk roads

ST	V_{GV} [km/h]	Range of traffic volume (veh./h per direction)		
		Empirical evidence	Transition at s=0, ku=0	Congestion
1.11,	$V_{GV} = 185{,}5 - 105 \cdot \cosh\left(\frac{s+1}{10}\right) + 2 \cdot \left(1 - \exp\left(3{,}045 \cdot 10^{-3} \cdot Q_{GV}\right)\right)$	≤1.000		
3.11	$V_{GV} = \coth\left(\left(Q_{GV} - 995{,}24\right) \cdot 10^{-2}\right) + 18{,}99$		>1.000	
	$V_{GV} = 20$			>1.250
1.21, 1.22,	$V_{GV} = 86{,}1 - 6 \cdot \exp\left(0{,}248 \cdot s\right) - 0{,}1 \cdot \exp\left(9{,}218 \cdot 10^{-3} \cdot Q_{GV}\right)$	≤650		
3.21, 3.22	$V_{GV} = \coth\left(\left(Q_{GV} - 645{,}26\right) \cdot 10^{-2}\right) + 18{,}93$		>650	
	$V_{GV} = 20$			>815
1.31, 1.32,	$V_{GV} = 86{,}1 - 6 \cdot \exp\left(0{,}248 \cdot s\right) - 0{,}1 \cdot \exp\left(4{,}609 \cdot 10^{-3} \cdot Q_{GV}\right)$	≤1.300		
3.31, 3.32	$V_{GV} = \coth\left(\left(Q_{GV} - 1.256{,}18\right) \cdot 10^{-3}\right) + 17{,}17$		>1.300	
	$V_{GV} = 20$			>1.625
1.41, 1.42,	$V_{GV} = 86{,}1 - 6 \cdot \exp\left(0{,}248 \cdot s\right) - 0{,}1 \cdot \exp\left(3{,}994 \cdot 10^{-3} \cdot Q_{GV}\right)$	≤1.500		
3.41, 3.42	$V_{GV} = \coth\left(\left(Q_{GV} - 1.455{,}58\right) \cdot 10^{-3}\right) + 17{,}48$		>1.500	
	$V_{GV} = 20$			>1.875

ST	V_{GV} [km/h]	Range of traffic volume (veh./h per direction) Empirical evidence	Transition at s=0, ku=0	Congestion
2.10	$V_{GV}=\left(166-85\cdot\cosh\left(\frac{s+1,5}{10}\right)\right)\cdot\exp\left(-10^{-3}\cdot KU\right)$ $+0,1\cdot\left(1-\exp\left(1,998\cdot 10^{-2}\cdot Q_{GV}\right)\right)$	≤300		
	$V_{GV}=\coth\left(\left(Q_{GV}-296,83\right)\cdot 10^{-2}\right)+8,47$		>300	
	$V_{GV}=10$			>375
2.11	$V_{GV}=\left(166-85\cdot\cosh\left(\frac{s+1,5}{10}\right)\right)\cdot\exp\left(-10^{-3}\cdot KU\right)$ $+0,1\cdot\left(1-\exp\left(1,998\cdot 10^{-2}\cdot Q_{GV}\right)\right)$	≤300		
	$V_{GV}=\coth\left(\left(Q_{GV}-296,83\right)\cdot 10^{-2}\right)+8,47$		>300	
	$V_{GV}=10$			>375
2.12	$V_{GV}=\left(146-85\cdot\cosh\left(\frac{s+1,5}{10}\right)\right)\cdot\exp\left(-10^{-3}\cdot KU\right)$ $+0,1\cdot\left(1-\exp\left(2,121\cdot 10^{-2}\cdot Q_{GV}\right)\right)$	≤250		
	$V_{GV}=\coth\left(\left(Q_{GV}-246,85\right)\cdot 10^{-2}\right)+8,26$		>250	
	$V_{GV}=10$			>315
2.13	$V_{GV}=\left(146-85\cdot\cosh\left(\frac{s+1,5}{10}\right)\right)\cdot\exp\left(-10^{-3}\cdot KU\right)$ $+0,1\cdot\left(1-\exp\left(2,652\cdot 10^{-2}\cdot Q_{GV}\right)\right)$	≤200		
	$V_{GV}=\coth\left(\left(Q_{GV}-196,88\right)\cdot 10^{-2}\right)+7,94$		>200	
	$V_{GV}=10$			>250
2.14	$V_{GV}=\left(136-85\cdot\cosh\left(\frac{s+1,5}{10}\right)\right)\cdot\exp\left(-10^{-3}\cdot KU\right)$ $+0,1\cdot\left(1-\exp\left(3,536\cdot 10^{-2}\cdot Q_{GV}\right)\right)$	≤150		
	$V_{GV}=\coth\left(\left(Q_{GV}-145,56\right)\cdot 10^{-2}\right)+7,48$		>150	
	$V_{GV}=10$			>190

ST	V_{GV} [km/h]	Range of traffic volume (veh./h per direction) Empirical evidence	Transition at s=0, ku=0	Congestion
2.21, 2.22	$V_{GV} = 91 - 6 \cdot \exp(0{,}248 \cdot s) - 5 \cdot \exp(3{,}38 \cdot 10^{-3} \cdot Q_{GV})$	≤650		
	$V_{GV} = \coth((Q_{GV} - 646{,}79) \cdot 10^{-2}) + 8{,}92$		>650	
	$V_{GV} = 10$			>815
2.31, 2.32	$V_{GV} = 91 - 6 \cdot \exp(0{,}248 \cdot s) - 5 \cdot \exp(1{,}69 \cdot 10^{-3} \cdot Q_{GV})$	≤1.300		
	$V_{GV} = \coth((Q_{GV} - 1.269{,}63) \cdot 10^{-3}) + 7{,}07$		>1.300	
	$V_{GV} = 10$			>1.625

Symbols:

ST	Road Type
V_P	Speed of passenger cars (Kph)
V_{GV}	Speed of goods vehicles (kph)
Q_P	Traffic volume of passenger cars (veh./h)
Q_{GV}	Traffic volume of goods vehicles (veh./h)
s	Gradient (%)
KU	Curvature (gon/km)