

Aircraft and high speed train
substitution:
The case for airline and railway
integration

Ph.D. thesis
The Bartlett School of Planning
University College London

Submitted by: Moshe Givoni

Supervised by: Professor David Banister

Professor Sir Peter Hall

February 2005

“This is the first page of my alskling husband’s Ph.D.There will be many more pages to follow and some of them will be written easily while others will take a bit longer and require more strength and thoughts. I want you to know that I will always be there to share all the happy moments of achievements with you and during times when you need help and support I will be there even more to encourage and inspire you”

(Helena, 18/01/2003).

To Helena, who put the first words in this Thesis, who was involved in every stage of the research, who always listened to and read my work again and again, and who all throughout gave me love, support, and encouragement without which it would never have been possible to complete this research

To my parents, sister, and brother for their support and love and for making homesick bearable



To David for inspiring supervision

Acknowledgments

Most people mistakenly think swimming is an individual sport. But while you compete as an individual, you train as a team and your success equally depends on both. Completing a PhD is the same. To successfully complete it you depend on the support from your team!

In this space I would like to present my team, acknowledge their help and support and, most important, convey my gratitude.

First of all, David Banister, who guided me in every step towards completion of the research and at the same time challenged me to find my own way to conduct it, who taught me so much, and was a role model as a supervisor professionally and personally. Next to David there was always Peter Hall whenever I needed advice, information, contacts, and mainly feedback on 'work in progress' or conference papers.

There were also my PhD friends, always there to exchange information, to offer their help and support, and to share the everyday life of PhD students (and to enquire about the budget). There were the transport people, who I always bothered with transport questions, Kang-Rae, Lloyd and Yuki and the rest of the gang: Doshik, Elisabete, Filipa, Joao, Johan, Nikos, Penny, Raul, Richard, Sonia, and Suzanne. Being surrounded by these people was a key to success!

There were many others involved in the research and securing my success. On the academic aspect I would like to thank Piet Rietveld from the Free University, Amsterdam and Yossi Berechman from Tel-Aviv University. Also many thanks to Mr. Andrew Sharp, chairman of the International Air Rail Organisation and Mr. Paul Le Blond (Paul Le Blond Consulting) for the help and for putting up with all my emails with request for information.

Special thanks go to the people who made sure I will keep healthy and fit, Margaret Hodson and Hannah Blau for the former, Leonid and Hadar for the latter.

I would also like to thank Tomer Goodovitch, Ziv Peer and Ronen Manash for the support.

This research would not have been possible without the generous financial support of the following: the Overseas Research Scholarship (ORS), the Anglo-Jewish Association (AJA), B'nai B'rit, the Anglo-Israel Association (AIA), Mrs. Reuma Weizman, Mrs. Hana Fride and the Israeli CF association, Mr. Avner Yehudai, the Recanati Graduate School of Business Administration at Tel-Aviv University, and the International Air Rail Organisation.

Abstract

Aircraft and High Speed Train (HST) operations usually result in competition between the airlines and the railways, leading the former to resist mode substitution and thus limiting its potential benefits. This research proposes a different model of substitution, one in which the airlines replace the aircraft by HST on some routes but continue to provide the services through code share agreements with the railways which operate the HST. In addition, the model assumes that the HST service is provided from the airport and is fully integrated with the rest of the airline's route network, leading to airline and railway integration.

Under this model, the research has shown that airlines benefit from integration (as well as the railways and the airports) and thus have an incentive to adopt mode substitution. Furthermore, passengers and society also benefit, the former from travel time savings and the latter from reduced environmental pollution, making integration a win-win option.

Adopting an empirical approach, the benefits from airline and railway integration are evaluated using Cost Benefit Analysis (CBA) and Multi Criteria Analysis (MCA) frameworks, and using the London Heathrow airport to Paris route as a case study. The analysis showed that HST and rail services at airports provide an alternative to investment in increasing runway capacity and that this secures additional benefits at a comparable cost.

Specifically for Heathrow, airline and railway integration was found to be the only option to resolve the Government's three main policy goals for the airport, namely preserving its international competitive position as a transfer/hub airport in order to secure its contribution to the national economy; increasing services from the regions, and thus accessibility from the regions to London and the rest of the world; and to curb its impact on the environment. Furthermore, integration between modes, a key policy target in the UK and the EU, is promoted. The above holds for other airports as well.

Following from the above, the research recommends adopting airline and railway integration as the model for aircraft and HST substitution and calls for the definition of air transport infrastructure to be changed and to include HST lines and stations.

On the methodological aspects, the use of a detailed empirical analysis, which includes the use of comprehensive evaluation practices, is recommended as the basis for forming transport policies. The analysis has shown that it is necessary to rely on the CBA results, but the recommendation is to support these results with MCA to provide evidence for its robustness. In addition, it was found that the common units of passenger-km are not always appropriate and that it is important to present the results in different units.

Table of contents

Acknowledgments.....	3
Abstract	4
Table of contents	5
List of tables.....	10
List of figures	12
List of abbreviations.....	13
Preface	15
1. INTRODUCTION.....	16
1.1 Research objectives and hypothesis	17
1.2 Research approach	18
1.3 The innovation, originality, relevance, and importance elements of the research	19
1.4 Structure of the thesis.....	21
2. RESEARCH CONTEXT AND BACKGROUND.....	24
2.1 THE PROBLEMS FACING THE AIR TRANSPORT INDUSTRY	25
2.1.1 The ATI congestion problem	27
2.1.2 The ATI impact on the environment.....	29
2.1.3 The socio-economic benefits of the ATI.....	32
2.1.4 Forecasts for growth in demand for air services and their implications	34
2.1.5 HST as a solution to the problems faced by the ATI.....	38
2.1.6 Conclusions.....	39
2.2. THE DEVELOPMENT OF THE HST.....	41
2.3 SUBSTITUTION AND COMPLEMENTARITY BETWEEN AIRCRAFT AND HST	44
2.3.1 Cooperation between the modes.....	47
2.3.2 Competition between the modes.....	49
2.3.3 Integration between the modes.....	52
2.3.4 The interface point between the train and the plane – the airport.....	56
2.4 AIRLINE AND RAILWAY INTEGRATION - A NEW APPROACH TO INTERMODALITY .	59
3. THEORETICAL AND METHODOLOGICAL FRAMEWORK.....	63
3.1 AIRLINE AND RAILWAY INTEGRATION - RESEARCH METHODOLOGY	64
3.1.1 Research methodology - the ideological approach.....	64
3.1.2 Research methodology - the empirical study: operating airline and railway integration	67

3.1.2.1 The case study route – London Heathrow to Paris.....	70
3.1.2.2 The empirical evaluation of operating airline and railway integration – data requirements.....	75
3.1.3 Conclusions.....	78
3.2 SOCIAL ECONOMIC EVALUATION.....	80
3.2.1 The financial analysis	81
3.2.2 Social economic evaluation – Cost Benefit Analysis and Multi Criteria Analysis.....	83
3.2.2.1 Monetary evaluation methods: the Cost Benefit Analysis	84
3.2.2.2 Non-monetary evaluation methods: the Multi-Criteria Analysis	87
3.2.3 Evaluating the benefits from the operation of airline and railway integration - conclusions.....	89
3.3 THE VALUE OF TRAVEL TIME SAVINGS (VTTS).....	93
3.3.1 The theory of the value of time	93
3.3.2 The use of the value of travel time savings in public transport.....	95
3.3.3 The use of the value of travel time savings in this research - conclusions	99
3.4 MEASURING THE IMPACT OF TRANSPORT OPERATION ON THE ENVIRONMENT ..	101
3.4.1 Evaluating the impact of transport operation on the environment.....	101
3.4.1.1 Evaluating the impact of aircraft and HST operation on the environment in this research	104
3.4.2 Comparing the impact of aircraft and HST operation on Local Air Pollution	105
3.4.2.1 Comparing aircraft and HST impact on local air pollution – empirical analysis	107
3.4.3 Comparing the impact of aircraft and HST operation on climate change.....	109
3.4.3.1 Comparing aircraft and HST impact on climate change – empirical analysis	112
3.4.4 Comparing the impact of aircraft and HST operation on noise pollution	114
3.4.4.1 Comparing aircraft and HST impact on noise pollution – empirical analysis	117
3.4.5 Conclusions.....	118
4. EVALUATING BENEFITS FROM OPERATING AIRLINE AND RAILWAY INTEGRATION	119
4.1 EVALUATING OPERATING COST BENEFITS TO AIRLINES FROM AIRLINE AND RAILWAY INTEGRATION	120
4.1.1 Aircraft operating costs.....	120

4.1.2 HST operating costs.....	122
4.1.3 Comparing the costs of operating HST and aircraft services between Heathrow and Paris.....	123
4.1.4 Conclusions and discussion.....	127
4.2 EVALUATING BENEFITS TO PASSENGERS FROM THE OPERATION OF AIRLINE AND RAILWAY INTEGRATION	130
4.2.1 Travel-time savings to passengers from airline and railway integration – time based analysis.....	132
4.2.2 Journey and mode characteristics.....	136
4.2.3 Travel-time savings to passengers from HST and aircraft substitution – a monetary based analysis.....	138
4.2.4 Conclusions.....	142
4.3 EVALUATING THE BENEFITS TO SOCIETY OF REDUCED ENVIRONMENTAL IMPACT FROM OPERATING AIRLINE AND RAILWAY INTEGRATION.....	145
4.3.1 Measuring potential reductions in local air pollution from shifting services from the aircraft to the HST	145
4.3.1.1 Emission from the aircraft and HST journeys.....	145
4.3.1.2 Impact on LAP from the aircraft and HST journeys.....	148
4.3.1.3 The cost of LAP from the aircraft and HST journeys	149
4.3.1.4 Measuring potential reductions in local air pollution from shifting services from the aircraft to the HST – conclusions	151
4.3.2 Measuring potential reductions in climate change from shifting services from the aircraft to the HST	154
4.3.2.1 Emission from the aircraft and HST journeys.....	154
4.3.2.2 Impact on Climate Change from the aircraft and HST journeys.....	157
4.3.2.3 The cost of climate change from the aircraft and HST journeys.....	160
4.3.2.4 Potential reductions in climate change from shifting services from the aircraft to the HST – conclusions	162
4.3.3 Measuring potential reductions in noise pollution from shifting services from the aircraft to the HST	164
4.3.3.1 Measuring potential reductions in noise pollution from shifting services from the aircraft to the HST - conclusions.....	167
4.3.4 Conclusions.....	169
4.4 BENEFITS TO AIRLINES, PASSENGERS, AND SOCIETY FROM THE OPERATION OF AIRLINE AND RAILWAY INTEGRATION – SUMMARY RESULTS.....	174
4.4.1 Benefits from airline and railway integration for every seat transferred from	

the aircraft to the HST	174
4.4.1.1 The Train Operating Company increase in capacity following airline and railway integration	179
4.4.2 Benefits from one year operation of airline and railway integration on the Heathrow - Paris route.....	181
4.4.3 Airline and railway integration at the airport level – the scope for benefits and the potential to alleviate congestion at Heathrow.....	183
4.4.3.1 The scope to free runway capacity at Heathrow through airline and railway integration	183
4.4.3.2 Benefits from airline and railway integration at Heathrow airport	187
4.4.4 Conclusions.....	189
5. AIRLINE AND RAILWAY INTEGRATION IN A WIDER PERSPECTIVE	193
5.1 ADDITIONAL BENEFITS FROM AIRLINE AND RAILWAY INTEGRATION.....	195
5.1.1 Additional benefits to airlines from airline and railway integration	195
5.1.2 Benefits to airports	198
5.1.3 Benefits to the railways	202
5.1.4 Conclusions.....	205
5.2 AIRLINE AND RAILWAY INTEGRATION IN A TRANSPORT POLICY CONTEXT – HST LINE VS. RUNWAY CAPACITIES AT HEATHROW	206
5.2.1 The case for provision of extra runway capacity in the South East of England and at Heathrow	207
5.2.2 Airline and railway integration as an option to increase capacity at Heathrow.....	211
5.2.3 HST policy in the UK	214
5.2.4 Conclusions.....	218
5.2.4.1 The effect of airline and railway integration on the level of competition.....	218
5.3 AIRLINE AND RAILWAY INTEGRATION IN PRACTICE	221
5.3.1 The cost of providing HST services at Heathrow	221
5.3.1.1 The cost of a HST link to Heathrow	221
5.3.1.2 The cost of a new runway at Heathrow.....	224
5.2.4.3 The capacity provided by a new runway and a new HST station at Heathrow	225
5.2.4.4. Conclusions.....	226
5.3.2 Elements of airline and railway integration in practice.....	227
5.3.3 The future of Hub & Spoke operation	232
5.4 CONCLUSIONS.....	237

6. DISCUSSION AND CONCLUSIONS.....	240
6.1 THE EMPIRICAL AND POLICY ASPECTS OF AIRLINE AND RAILWAY INTEGRATION - CONCLUSIONS	241
6.1.1 The results	241
6.1.2 The main implications of the results	244
6.1.3 Policy recommendations	245
6.2 AIRLINE AND RAILWAY INTEGRATION - THE METHODOLOGICAL ASPECT.....	250
6.2.1 Airline and railway integration – an evaluation framework	250
6.2.2 The use of evaluation practices by decision makers	255
6.3 CONCLUSIONS AND FURTHER RESEARCH.....	259
BIBLIOGRAPHY.....	265
APPENDICES.....	278
APPENDIX A: ANALYSIS OF DELAYS IN THE EUROPEAN AIR TRANSPORT INDUSTRY	279
APPENDIX B: THE DEVELOPMENT OF THE HST.....	283
APPENDIX C: THE MAIN POLLUTANTS AND GASES ASSOCIATED WITH AIRCRAFT AND HST OPERATION IMPACT ON LOCAL AIR POLLUTION	299
APPENDIX D: NOISE STANDARDS AND THE MEASUREMENT OF NOISE	301
APPENDIX E: CALCULATION OF AIRPORT AND ATC CHARGES.....	305

List of tables

Table 1: Typology of relationships between rail and air service operators	45
Table 2: Categorization of rail links to airports based on geographical coverage	48
Table 3: Aircraft and HST competition on the Tokaido and Sanyo Shinkansen	51
Table 4: Aircraft and HST route distance for different routes	70
Table 5: HST and aircraft market share on the London-Paris route	71
Table 6: Models of aircraft used between Heathrow and CDG during summer 2003	74
Table 7: Categories of airline and HST operating costs	83
Table 8: The Landing Take Off cycle	107
Table 9: Aircraft operating costs and performance	121
Table 10: Direct operating costs of a flight from Heathrow to CDG	121
Table 11: Forecast for the rail company's HST services for 2002	122
Table 12: OCs of HST services forecasted for 2002	123
Table 13: Direct OCs of a HST service on the case study route	123
Table 14: Aircraft and HST OCs on the Heathrow to Paris route	124
Table 15: A320 OCs on the Heathrow - CDG route under different assumptions	124
Table 16: Aircraft and HST OCs on the Heathrow to Paris route assuming different charges	125
Table 17: Routes chosen for analysis of travel time savings	131
Table 18: Components of the aircraft and HST options of travel	131
Table 19: Time based comparison between the aircraft and the HST journeys	133
Table 20: Framework for HST and aircraft journey time comparison	136
Table 21: Comparison between aircraft and HST journey characteristics	138
Table 22: Monetary based comparison between the aircraft and the HST journeys	140
Table 23: Emission during the LTO cycle for A320 and B737	145
Table 24: Emissions during the egress journey	146
Table 25: Emissions from the HST journey	147
Table 26: Comparison of emission from the aircraft and HST journey	147
Table 27: Comparison of emissions from the aircraft and HST journey using toxicity factors	148
Table 28: Damage cost estimates for different pollutants and the toxicity factor	150
Table 29: Comparison of the cost of LAP imposed by aircraft and HST journeys	150
Table 30: LAP indicators from aircraft and HST journey	152
Table 31: A320 flight characteristics and emissions for the case study route	155
Table 32: Emissions during the Heathrow-CDG flight for the A320 and B737 aircraft	156
Table 33: Emissions during the egress journey	156

Table 34: Emissions from the HST journey.....	156
Table 35: Comparison of emission from the aircraft and HST journeys	157
Table 36: Impact of aircraft and HST operation on climate change	158
Table 37: Impact of aircraft and HST operation on climate change	159
Table 38: Comparison of the cost of Climate Change imposed by aircraft and HST journeys	161
Table 39: Climate Change impact indicators for aircraft and HST journey	163
Table 40: Number of people exposed to noise levels of SEL of 90 or 100 dB(A) and above per seat provided on the route	166
Table 41: List of gases/pollutants included in the analysis of LAP and climate change	170
Table 42: Comparison of the cost of LAP and Climate Change imposed by aircraft and HST journeys	171
Table 43: Benefits from airline and railway integration on the Heathrow-Paris route	175
Table 44: Benefits from airline and railway integration on the Heathrow-Paris route	177
Table 45: Benefits from airline and railway integration on the Heathrow-Paris route	179
Table 46: Benefits from airline and railway integration on the Heathrow-Paris route under different increases in the HST capacity.....	180
Table 47: Benefits from airline and railway integration from one year of operation, MCA	182
Table 48: Benefits from airline and railway integration from one year of operation on the Heathrow-Paris route, CBA	182
Table 49: Routes from Heathrow suitable for consideration of aircraft and HST substitution	184
Table 50: Routes from Heathrow suitable for consideration of aircraft and HST substitution	185
Table 51: The scope to alleviate congestion at Heathrow through airline and railway integration	186
Table 52: Direct connectivity between CDG, Schiphol and Zaventem airports	199
Table 53: 'Hubbing' connectivity of Schiphol and CDG airports with respect to different markets	200
Table 54: Market share on the London-Paris and London-Brussels routes	219
Table 55: The cost of increasing Heathrow's capacity from 86 to 112 mppa by constructing a third runway	225
Table 56: The main indirect benefits from airline and railway integration	238

List of figures

Figure 1: General structure of the thesis	23
Figure 2: The air-transport-system capacity components.	26
Figure 3: Passenger kilometres flown by all commercial airlines of the world 1960-1998... 27	
Figure 4: Actual and forecast passenger numbers at UK airports, 1975 to 2020.....	36
Figure 5: Typology of relationships between rail and air service operators	45
Figure 6: Aircraft and HST options of travel between the hub airport and the destination city	66
Figure 7: Aircraft and HST options of travel between Heathrow and Paris	73
Figure 8: Map of the case study route.....	74
Figure 9: The use of evaluation tools in this research.....	80
Figure 10: summary table of MCA for airline and railway integration	89
Figure 11: The pathway to evaluate transport operation impact on the environment.....	102
Figure 12: The atmosphere layers and aircraft's flight and cruise altitude.....	111
Figure 13: Comparison of the cost of LAP and Climate Change imposed by aircraft and HST journeys, and the consequent benefits.....	171
Figure 14: The layout of the proposed 3 rd runway and 6 th terminal at Heathrow in relation to the existing facilities.....	210
Figure 15: HST lines construction costs (€millions per km)	223
Figure 16: models of hub airports in a hub & spoke system.....	231
Figure 17: The irreconcilable policy targets for Heathrow	244

List of abbreviations

ACI – Airport Council International
AEF – Aviation Environment Federation
Aer. - Aerosols
ATAG – Air Transport Action Group
ATC – Air Traffic Control
ATI – Air Transport Industry
ATM - Air Transport Movement
AVE - Alta Velocidad Espanola (Spanish HST)
BALPA - British Air Lines Pilots Association
CAA – Civil Aviation Authority
CAEP - Committee on Aviation Environmental Protection
CBA - Cost Benefit Analysis
CDG – (Paris) Charles de Gaulle (airport)
CEC - Commission of the European Communities
CfIT – Commission for Integrated Transport
CO - Carbon Monoxide
CO₂ - Carbon Dioxide
CODA – (Eurocontrol’s) Central Office for Delay Analysis
CTA – Central Terminal Area
CTRL - Channel Tunnel Rail Link
CRS - Computer Reservation System
CUV - Constant Unit Value
DB - Deutsche Bahn (German railways)
DEFRA - Department for Environment, Food & Rural Affairs
DETR – Department of the Environment, Transport and the Regions
DfT – Department for Transport
DTLR - Department of Transport Local government and the Regions
DUV - Discounted Unit Value
DVT - Deep-Vein Thrombosis
EC – European Commission
ECAC – European Civil Aviation Conference
EPA - Environmental Protection Agency
EU – European Union
FA – Financial Analysis
GDP – Gross Domestic Product
GHG – Green House Gas
GOMMMS - Guidance on the Methodology for Multi-Modal Studies
GWP - Global Warming Potential
H₂O - Water Vapour
HACAN - Heathrow Association for the Control of Aircraft Noise
HC - Hydrocarbons
HST – High Speed Train
H&S – Hub and Spoke
IARO – International Air Rail Organisation
IATA – International Air Transport Association
ICAO – International Civil Aviation Organization
ICE - Inter-City Express (German HST)
IPCC - Intergovernmental Panel on Climate Change
IRJ – International Railway Journal
IVT - In-Vehicle Time
LAP – Local Air Pollution
LF – Load Factor

LTO - Landing Take-Off
MCA - Multi Criteria Analysis
MCT - Minimum Connecting Time
MPPA – Million Passengers Per Annum
MTOW – Maximum Take-Off Weight
NATA – New Approach To Appraisal
NDSI – Noise Depreciation Sensitivity Index
NO_x - Oxides of Nitrogen
NS - Nederlandse Spoorwegen (Dutch railways)
O₃ - Ozone
OC - Operating Costs
ODPM - Office of the Deputy Prime Minister
OEF – Oxford Economic Forecasting
OVT - Out of Vehicle Time
PSO - Public Service Obligation
PM – Particulate Matter
RCEP - Royal Commission on Environmental Pollution
RF - Radiative Forcing
RP - Revealed Preference
RPK - Revenue Passenger Kilometres
SACTRA - Standing Advisory Committee on Trunk Road Assessment
SARS – Severe Acute Respiratory Syndrome
SCBA - Social Cost-Benefit Analysis
SNCF – Societe Nationale des Chemins de fer Francais (French railways)
SO₂ - Sulphur Dioxide
SP - Stated Preference
SRA - Strategic Rail Authority
T5 – (Heathrow) Terminal 5
T6 – (Heathrow proposed) Terminal 6
tC – Tonne of Carbon
TEN-T – Trans-European Network – Transport
TIM – Time In Mode
TOC - Train Operating Company
TGV - Train à Grande Vitesse (French HST)
VOC - Volatile Organic Compounds
VOT – Value Of Time
VTTS - Value of Travel Time Savings
WCML - West Coast Main Line
WTP - Willingness To Pay

Airlines:

AF – Air France
BA – British Airways
LH – Lufthansa
KLM – Royal Dutch Airlines
SAS – Scandinavian Airlines

Preface

In June 1999 I came to the UK and for the first time met with David Banister to discuss the possibility for me to start a PhD in transport under his supervision. After a short introduction he went straight to the point: “so what is your great idea?” Not having any idea, just a very strong self belief that an academic career as an expert in transportation is what I will be good at and enjoy, I realised that I should start thinking of another supervisor and university, because here I will not be accepted. Luckily, David did not show me the door straightaway. We continued discussing my interests and research possibilities and I explained that aviation (airlines, airports, etc.) is definitely my favourite subject but I also have an interest in railways.

That same morning I had travelled to London from Birmingham and to my great surprise, while waiting for the train, I saw “Virgin” trains on all the platforms, a known airline as far as I knew until then. First stop on the journey to London was Birmingham International airport where most of the people boarding were business people, who apparently had just flown in. Why on earth will someone who wants to get to London fly to Birmingham to catch a train to London, I thought?

It took me some time to make sense of it (it seems clever today, if you have a meeting in Euston and you come from Amsterdam, for example) but the important thing was that the seed for the subject of my PhD had been planted. It was obvious when I left David’s room that day. I had found THE idea, now I could start my PhD.

To make it from that day to today maybe took a long time but the way was always clear and with David’s guidance relatively trouble free. So, what then was a logical way of travelling for those travellers I hope will now be more than just commonsense but something that has been thoroughly researched and proved. Nevertheless, it is still, in my view, simply logical that air and rail networks and services should be integrated.

I believe that in the future integrated air and rail services will be the norm and that it might look strange that to suggest it a PhD research was needed.

1. Introduction

Ever since the development of the modern High Speed Train (HST) in the 1960s, it became apparent that rail services can offer some of the services provided hitherto by aircraft. Consequently, it has been constantly suggested ever since that HST services should replace aircraft services because of the environmental burden the latter impose and the lack of capacity at major airports. Such claims were made already in the early 1970s (e.g. Bromhead, 1973) when the world annual air passenger traffic was 0.4 trillion passenger-kilometres (in 1969) (Humphreys, 2003). 30 years later, with 3 trillion passenger-kilometres (in 1999, *ibid*), and with the environmental and capacity problems proportionally exacerbated (the environmental problem very much due to increased awareness of, and research on, the problem), the calls for mode substitution are increasingly louder.

However, the calls come almost entirely from outside the Air Transport Industry (ATI) since substituting aircraft by HSTs means loss of business for the ATI. On routes where HST services have been introduced, the HST has usually gained a significant, and often the biggest, part of the market share. Yet, in many cases the airlines, for different reasons, have continued to compete with the railways, often, by increasing the number of services (using smaller planes) to keep some market share. This means that mode substitution could lead to an increase in environmental pollution and capacity shortages at airports, rather than the other way round.

Recognising the potential benefits from mode substitution, this research proposes a different model for aircraft and HST substitution, one in which the airlines have incentives to adopt substitution. This can happen when the airline continues to provide the services and thus retain its passenger (market) even after the mode used has been changed. The model of airline and railway integration provides that. Under this model, HST services are provided from the airport and the airline uses the HST as an integrated part of its (aircraft) route network. The airline does not have to operate the HST service. It is enough that the airline reaches an agreement with the Train Operating Company (TOC) for the latter to serve the airline passengers and for the two to integrate their services to the extent that from the passenger perspective using, within one journey, two of the airline's aircraft services would be similar to using the train and the plane. Hence, airline and railway integration!

This research, therefore, examines aircraft and HST substitution, a subject that merits much further research than has been done to date, but based on a different model of substitution,

one that leads to cooperation and not competition between the industries and thus allows for the potential benefits from substitution to materialize.

The examination is through an empirical analysis of the potential benefits, and wider implications, from airline and railway integration, for society, passengers, and the respective industries. The analysis focuses on the evaluation of the benefits using an array of evaluation methods and practices. In making, step by step, the case for airline and railway integration, utilising best practice in evaluation techniques, the use of these techniques is put to the (empirical) test, is criticised, and eventually improved.

The fast and many changes in the UK transport arena in recent years, with regard to the rail and air transport industries, and the empirical nature of the research meant that the work had to be constantly updated with events that took place and still happening. For practical reasons, as the writing came to an end, it was necessary to draw a line and end the research. Therefore, events which took place after 1 June 2004 are not addressed in the research.

1.1 Research objectives and hypothesis

The main aim of the research is to empirically evaluate the benefits from aircraft and HST substitution under airline and railway integration. These benefits are many and are likely to be experienced by different stakeholders in different, sometimes opposite, ways. These stakeholders can be divided into three groups: the operators, the customers, and society.

From the above aim stem the three main objectives of the research. First, to provide an empirical evidence of the benefits to airlines, passengers, and society from airline and railway integration. Second, and based on the evidence found, is to provide policy recommendations regarding aircraft and HST substitution in general and specific recommendations for the case study used. For various reasons, discussed in the research, the evaluation of benefits from airline and railway integration is expected to be different, and more complicated, than common evaluation practices. From this stems the third objective of the research, which is to empirically examine the use of current evaluation methodologies, suggest ways to improve them, and recommend an approach to evaluate airline and railway integration.

Following the objectives set above the following hypothesis is tested:

The operation of airline and railway integration would lead to operating cost savings to airlines, travel time savings to passengers, and reduced environmental

pollution to society. In addition, it would provide additional capacity to airports, at the same costs and with less environmental pollution than new runways would, and it would provide the same economic benefits and more accessibility than new runways would. Finally it would be more consistent with declared transport policies. Therefore, aircraft and HST substitution under airline and railway integration will be a win-win option for all stakeholders involved.

Testing the above hypothesis is at the centre of the research and its core contribution.

1.2 Research approach

Integration between the airlines and the railways takes place on routes where the HST and the aircraft journeys complement each other, but the train substitutes the aircraft on the railway segment of the journey. Hence, if originally the passenger flew to an airport and transferred to another flight, under airline and railway integration, the passenger flies to an airport and transfers to the HST. In terms of the service provision the passenger feels no difference between the two situations.

From the outset it was recognised that airline and railway integration would have many effects, and many more if the evaluation considers a case study where the HST infrastructure is not available. In this case many of the effects were not expected to be directly related to airline and railway integration but to the investments in it. Therefore, the evaluation was divided between the operation of airline and railway integration, where infrastructure investments are not required, and the wider aspect of it, or between the direct and indirect benefits.

In the evaluation of direct benefits from the operation of airline and railway integration, two journeys were compared, with and without integration, to estimate the benefits. The evaluation first considered, separately, each group of stakeholders to allow for a detailed analysis. These were the airlines, which were expected to gain operating cost savings from the operation of airline and railway integration; passengers who were expected to benefit from travel time savings, and society which was expected to benefit from reduced environmental impact. After these benefits were estimated, they were summed up to yield the net benefits from the operation of airline and railway integration.

Following the evaluation of direct benefits, considered to be the focus of the research, the research focus was broadened to include evaluation of other benefits and to consider important aspects of airline and railway integration. The evaluation, which was in a qualitative rather than a quantitative manner, considered benefits to the airport and railway,

and additional benefits to the airlines. These benefits were also from the improved rail connections to the airport and not only from the substitution of aircraft by HSTs. By considering how airline and railway integration, and the benefits it provides, fit in with aviation, railways, and general transport policies, benefits to society other than environmental benefits were considered. Finally, the research considered the investments required and how the concept of integration between airline and railway services would 'blend' into the ATI.

The fact that HST services substitute aircraft services means that a HST link to an airport can substitute the runway. This element of integration was emphasised when integration was considered in a wider perspective. The reason the research focus is very much on the airlines, within the operator stakeholder group, is because it is considered to be the airline's decision if to substitute the aircraft or not. It does not mean that the airport or the railway would not gain, they might, and maybe even more. Furthermore, airlines might substitute the aircraft with HST, but the TOCs would not consider substituting the HST with the aircraft.

1.3 The innovation, originality, relevance, and importance elements of the research

The rapid growth in the world air passenger traffic is forecast to continue into the future. A 'middle case' forecast predicts that the world annual traffic would reach 5 trillion passenger-kilometres in 2009 and 8 trillion in 2019 (Humphreys, 2003)¹. With this growth, the capacity and environmental problems faced by the ATI and affecting passengers and society would significantly intensify. At the same time, and mainly within Europe, the HST network is expanding. Yet, it seems mode substitution has almost no impact on the ATI operation. The main reason is believed to be the fact that the airline service starts at the airport and the HST service at the city centre.

The model of airline and railway integration and the fact that the HST service begins at the airport and is integrated with the airline services is an innovative approach to investigate mode substitution. This, it is believed, would allow to consider a range of benefits from mode substitution which do not exist under the traditional model of mode substitution, for example, cooperation between the industries in other elements of operation.

In 1995, Buchanan and Partners (1995) were commissioned by the European Commission (EC) to research on "optimizing rail/air intermodality in Europe". Despite the title of their

¹ This forecast, by the ICAO, was made before the September 11 terrorist attacks in the US, but forecasts have now return to predict similar growth in air transport (see section 2.1.4).

research the research itself considers airline and railway integration to the extent of using the rail as a mode to access the airport, which actually suggests that cooperation is between the railway and the airport. A few years later, the COST-318 research on the “interaction between high speed and air passenger transport” (EC, 1998) also examined intermodality. In the study, more attention for aircraft and HST substitution was given, but it was focused mainly on the competition element of mode substitution, and also on the use of the rail as an access mode to airports. It also examined the effect of rail connections to airports on the airports themselves. With regards to airline and railway integration the study mainly described failed experiences. In contrast to the above research, this research begins with a very optimistic view of the potential benefits (a true and full) airline and railway integration can bring. Furthermore, when in 2001 Lufthansa (LH) started to operate services that amounted to ‘airline and railway integration’ there was still no comprehensive research of such operation which looked beyond the interests of the airline². This research recognises this gap in the literature, and more important, in the consideration of airline and railway integration, and it aims to fill it.

Before this research was completed, another comprehensive study on air/rail intermodality was published, this time by the airlines’ biggest organisation, the International Air Transport Association (IATA). This study focused on airline and railway integration, in the way it is envisaged in this research, but “set out to collect information from representatives of all the key players (airlines, railways, airports, and passengers) about their views on the development and promotion of European High Speed Rail” (IATA, 2003: 3, my emphasis), and therefore does not fulfil the need for thorough evaluation of airline and railway integration. Furthermore, it does not consider the environmental aspect of intermodality, one of the most important aspect to examine when considering mode substitution.

With respect to transport policy, the EU, it seems, has recognised the potential in cooperation between aircraft and HSTs. This recognition is reflected in its policy documents³, but did not yet materialize into actions (for example, the development of the HST network does not include any connection to an airport which is directly supported by the EU). In the UK, there is not even this recognition, it seems. This research hopes to provide policy makers with enough evidence for them to be bolder in taking actions towards real cooperation between the ATI and the railway industry, mainly through airline and railway integration.

² As well as on the interest of the airlines since LH does not reveal much on its ‘Airail’ services.

³ For example, “Network planning should therefore seek to take advantage of the ability of high speed trains to replace air transport and encourage rail companies, airlines and airport managers not just to compete, but also to cooperate”(CEC, 2001: 53, emphasis in original text).

In the UK, the above becomes an urgent need in light of the government recent publication of air transport policy for the next 30 years, which includes the construction of new runways, but does not even consider airline and railway integration. Before the 'go ahead' is given for the construction of new runways in London, and specifically at Heathrow, real consideration for airline and railway integration must be given. This research, by focusing on Heathrow and adopting an empirical approach, will provide the evidence to allow such consideration. In this respect the research is remarkably timely.

The focus of the research on airline and railway integration and the choice of an empirical approach present several methodological challenges in the evaluation process. The literature does not provide much information on how these can be overcome in practice. By empirically evaluating airline and railway integration this research provides an insight into the gap between the theory of evaluation and the practice of it. By overcoming this gap, the research contributes to the theory, improves empirical practices, and suggests an innovative methodology for using evaluation methods.

Specifically, with regard to the methodological aspect, this research deal with the comparison between two different modes within one evaluation, the use within one journey of two modes (this was mainly a challenge with respect to the value of travel time savings), and the evaluation of environmental impact from transport operation and especially the impact from aircraft operation at high altitude. Recognising that there is a need to deal with these methodological issues resulted in a detailed description of the evaluation process and this provides an insight into the way results were obtained, and thus makes the results more meaningful, especially for decision makers who can themselves judge their robustness.

1.4 Structure of the thesis

Following this introduction, the background for airline and railway integration is provided (section 2). It begins by describing the problems faced by the ATI in the face of growing demand for air travel (section 2.1). It also describes the ATI's operation impact on the environment which often is the main reason mode substitution is suggested. Then, the development of the HST is briefly discussed (section 2.2). The first two sections in the background part allow to examine three different relationships between airlines and railways (section 2.3): cooperation, competition, and integration, the latter is the basis for aircraft and HST substitution in this research. The role of the airport in mode substitution is also discussed in this section. Section 2 concludes by setting the context of the research (section 2.4).

The next two parts are, to a great extent, the focus of the research: the evaluation of benefits from operating airline and railway integration. Section 3 describes the methodology adopted for the evaluation and provides the theoretical background for the evaluation of airline and railway integration, while section 4 describes how the evaluation was carried out and its results.

Section three begins by explaining the methodology adopted to evaluate the benefits from airline and railway integration (section 3.1). Then the theoretical background for social economic evaluation is given, with more details on how such an evaluation was performed in the research (section 3.2). Specific attention is then given to the two main challenges in the evaluation: measuring the value of travel time savings (section 3.3) and measuring transport operation impact on the environment (section 3.4).

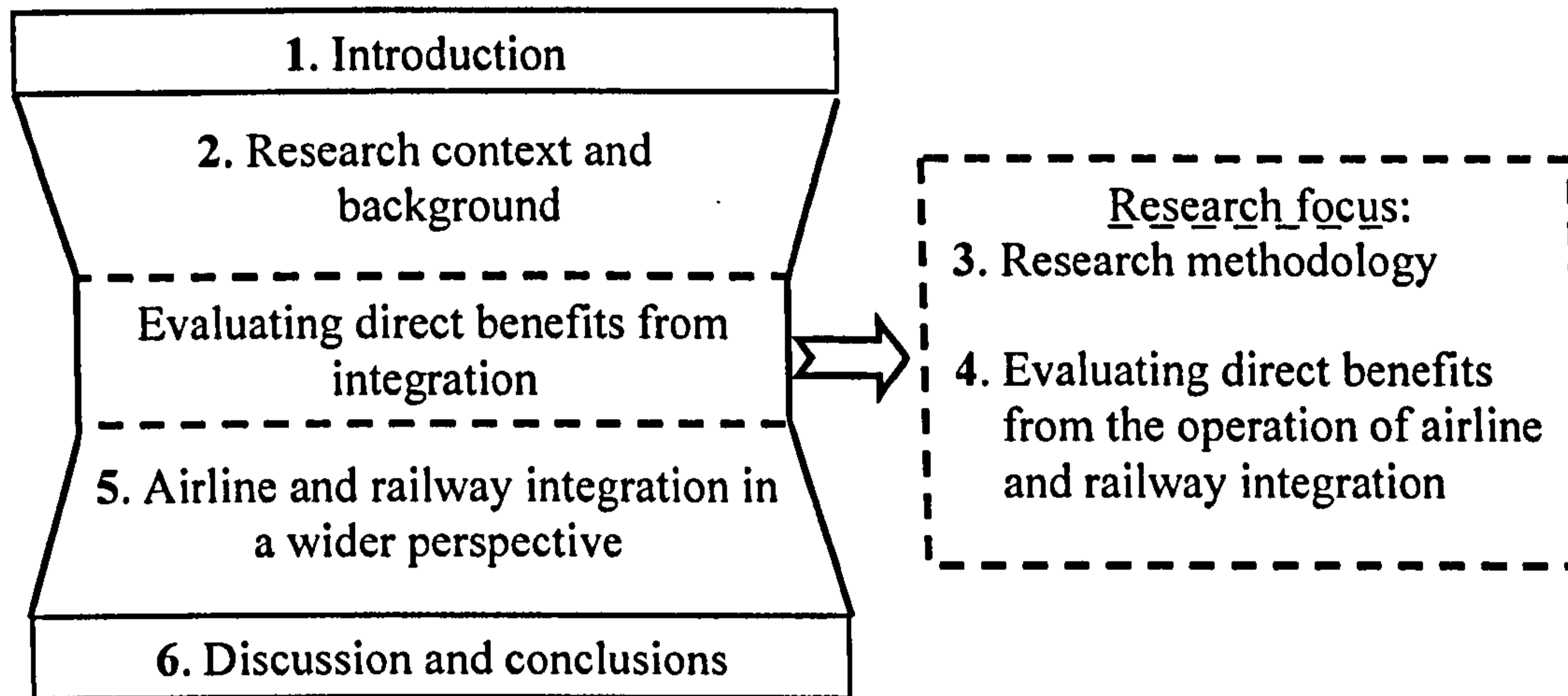
Section four is divided into four parts. The first three consist of separate evaluations according to groups of stakeholders. First, the analysis of operating cost savings to airlines is presented (section 4.1), followed by the analysis of travel time savings to passengers (section 4.2), and the analysis of environmental benefits to society (section 4.3). The fourth section sums up the benefits for the three stakeholder groups (section 4.4). In addition, the potential to free capacity at the case study airport is evaluated by considering the routes that are suitable for airline and railway integration and the level of services on these routes. This allows to estimate the magnitude of the measured benefits at the airport level as well as at the route level.

Based on the evaluation of direct benefits from airline and railway integration, the research focus is broadened in section 5 to consider the wider effect of airline and railway integration. First, additional benefits to the airlines, the airports, and the railways are evaluated (section 5.1). Then airline and railway integration is considered from a policy perspective (section 5.2) examining first current aviation policies in the UK and then how integration fits in with these policies. The discussion also considers current policies for the railway and how integration could fit in that respect. Finally, airline and railway integration in practice is discussed (section 5.3). Attention is first given to estimate the investments required for integration, and how these compare to investments in a new runway. Second, physical and cultural barriers in bringing the air and rail industries closer, essential for integration to work, are discussed. Third, current and future trends and changes in ATI are examined to estimate the future scope for airline and railway integration. In section 6 conclusions are drawn, first with regard to the empirical and policy aspect of integration (section 6.1) and then the methodological aspects of the evaluation of it in this research (section 6.2). The

research ends with predictions for future airline and railway integration and suggestions for further research (section 6.3).

The structure of the thesis is summarised in Figure 1.

Figure 1: General structure of the thesis



2. Research context and background

This section provides the background for the research. It begins by describing the current problems facing the Air Transport Industry (ATI), which are usually the reason for considering substitution of aircraft services by HST services. These problems include congestion at airports and in the sky, and the ATI impact on the environment. The next part (2.2) very briefly describes the development of the HST as a mode that can match aircraft performance, on some routes, in terms of travel time. A detailed discussion on the development of the HST is given in Appendix B and it also describes the development of the HST network, especially within Europe, which determines the scope for possible aircraft and HST substitution. The third section (2.3) defines three relationships between the airline and the Train Operating Company (TOC) that operates the HST services. These are cooperation, competition, and integration, with the last being at the centre of this research. A concluding part (2.4) based on the background information sets the context for evaluating aircraft and HST substitution under airline and railway integration.

2.1 The problems facing the Air Transport Industry

The success and growth of the Air Transport industry (ATI) in the last four decades is demonstrated by the almost 9% yearly increase in passenger traffic since 1960 (IPCC, 1999). This has brought with it problems that hinder the industry operation and its ability to serve the still rising demand for its services. These problems underpin the research on airline and railway integration at the centre of which aircraft and HST substitution is examined. This section sets the context to the research by describing and discussing two of the main problems faced by the ATI: congestion and environmental problems. In addition, this section discusses the forecasts for growth in demand for air services, which are expected to exacerbate the problems. This is followed by a discussion of possible solutions, which will emphasize the use of HST to solve, or at least alleviate, these problems.

It is useful to begin the discussion by dividing the ATI into different components of capacity with regard to the operation of passenger services. An airline passenger's journey starts when they leave their origin and ends when they arrive at their destination. Those origins and destinations are almost never at the airport. Accordingly, the air transport system stretches beyond the movement of aircraft between airports. In general, the air transport system can be broken down into five major components, each with its own capacity, which passengers must experience as they use commercial air transport services. These components are: access-to-airport capacity, airport land-side capacity, airport air-side capacity, airspace (or ATC - Air Traffic Control) capacity, and air transport system environmental capacity (Figure 2).

Access-to-airport capacity refers to the ground transportation network that connects to the airport. Any mode of surface transport that is used by passengers to arrive at, or leave from, the airport is part of this system. For research purposes, there is often division between public transport modes used to access the airport (e.g. rail, metro, bus) and private transport (i.e. cars including taxis).

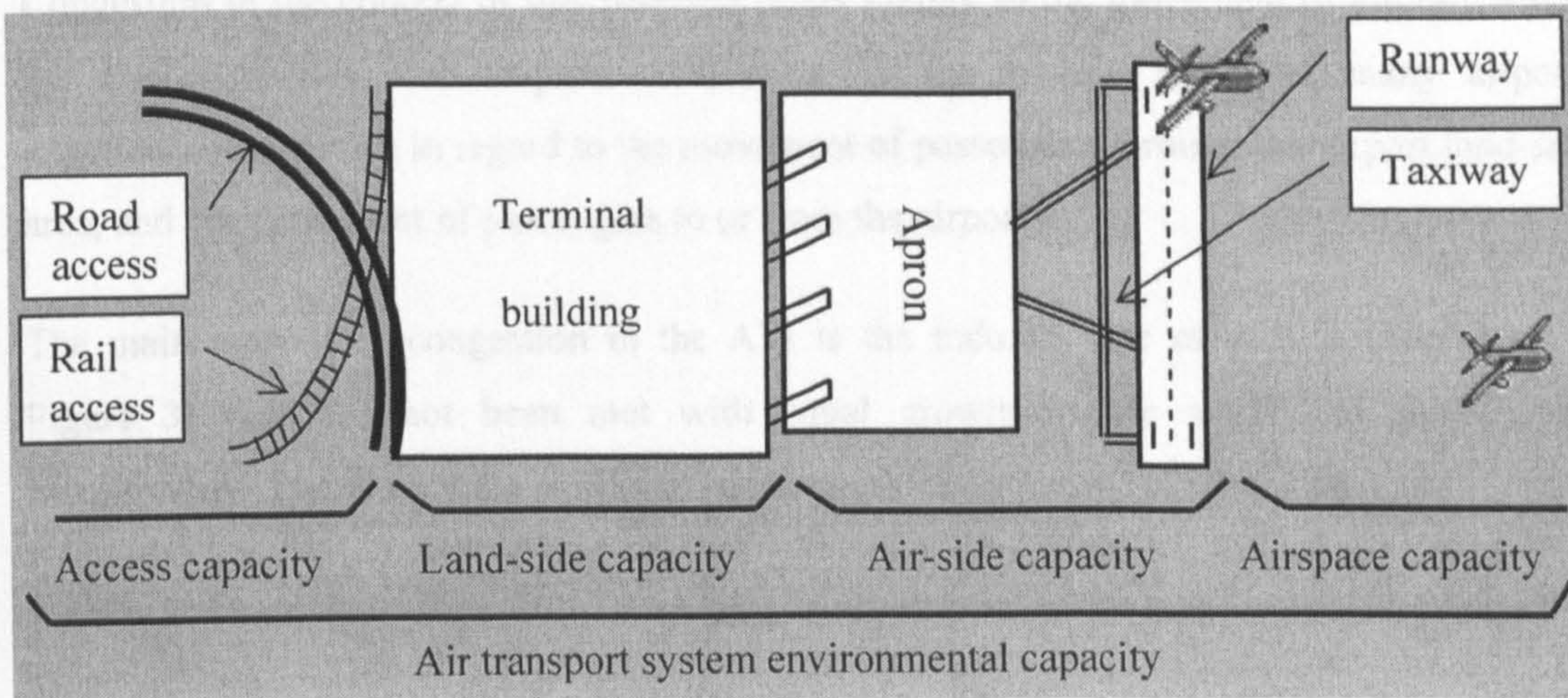
Airport land-side capacity is considered, in this research, to consist of the car parking areas, public transport facilities, and the terminal building(s), including the gates, and all the activities that take place within them.

Airport air-side capacity is considered to consist of the system of runway(s) with adjacent airspace (airport zone), taxiway system and apron/gate complex. The airport air-side capacity

is usually determined by the runway(s) capacity. In turn, runway capacity is mainly determined by the airport ATC separation standards; the runway location and position in relation to other runways in the airport or in nearby airports; the mix of aircraft using the runway; the configuration of the exits and taxi-ways associated with the runways; and the weather conditions (Janić, 2000).

2.1.1 The ATC congestion problem

Figure 2: The air-transport-system capacity components.



'Airspace' (or *Air Traffic Control*) capacity consists of the entire airspace outside the airport zone where the ATC system provides complete control over aircraft while flying. The 'airspace' capacity is solely determined by safety regulations which determine the minimum separation (vertically and horizontally) between flying aircraft. The regulations in turn are decided according to the controller's workload capabilities and ability to keep the aircraft from colliding while flying. The controllers' capabilities depend to a great extent on the ATC systems they have to work with.

Air transport system environmental capacity is virtually unlimited as long as there are no regulations imposed defining the system's environmental capacity. In recent years, many civil aviation authorities have imposed such a regulation (concerning mainly noise and emission levels) on airports, thus creating a real environmental capacity.

Except for *Airspace capacity*, passengers use/effect each component's capacity twice during one journey. Therefore, except for the *Air capacity* component, which is common to all airports, the other component capacity relates to an individual airport. The capacity of the system overall depends on the component with the least capacity. In terms of physical capacity, the runway is usually the controlling element of the airport's system capacity (Reynolds-Feighan and Button, 1999). In the context of this research, the environmental capacity component is also considered to be the system's controlling element.

According to the definitions above, HST services to/from airports are part of the access-to-airport capacity component. However, if airline and railway integration, in the way proposed in this research, is adopted by airlines, then the HST services will be part of the airport air-side capacity and will affect the system airspace capacity.

2.1.1 The ATI congestion problem

Congestion in the context of this research refers mainly to the movement of aircraft within the airport air-side and airspace components of the system. However, many airports experience congestion in regard to the movement of passengers through the airport land-side area, and the movement of passengers to or from the airport.

The main reason for congestion in the ATI is the industry rate of growth (illustrated in Figure 3) that has not been met with equal growth in the supply of air-transport infrastructure, and mainly the supply of adequate runways and ATC capacities.

Figure 3: Passenger kilometres flown by all commercial airlines of the world 1960-1998

Image removed due to third party copyright

Source: Nielsen (2001).

An additional contributor to the problem is the airlines' way of operation in the competitive market that evolved after the deregulation of the industry, especially in North America and Europe. This refers, more specifically, to the Hub-and-Spoke (H&S) way of operation (Button, 1991, Doganis 2002a+b), in which passengers are flown to their destination through a central airport, the hub airport, where they need to change aircraft in order to continue the journey to their destination. The passengers who arrive at an airport that is not their final destination in order to change aircraft are commonly referred to as transfer, transit,

interlining or connecting passengers⁴. Accordingly, a hub airport is “an airport whose facilities are planned to handle large volumes of connecting passengers in a short space of time” (Doganis, 2002b: 1). By definition, a H&S operation results in an overall increase in the number of flights at the hub airport.

At the world’s largest airports, transfer passengers take-up a significant part of the airport passenger capacity. In the two largest airports in the world (in terms of passenger volume), Atlanta and Chicago, 63% (51 million), and 53% (38 million) of the passengers were transfer passengers (in 2000) respectively. Also, in the leading European airports the proportion of transfer passengers in the airports’ overall passenger volume was significant. During 2000, 58% (27.9 million) of the passengers at Paris Charles de Gaulle (CDG) were transfer passengers, in Frankfurt airport this was 50% (24.5 million), in Amsterdam airport 41% (16.1), and in London Heathrow (Heathrow) 34% (21.9) (Doganis, 2002b). Despite the increase in the operation of low-cost airlines that operate point-to-point services, often by passing major hubs, major schedule airlines, such as British Airways (BA), Air France (AF), and KLM are likely to continue using the H&S operation at their respective hub airports Heathrow, CDG, and Schiphol. Because H&S operation is a fundamental element in airline and railway integration (see section 2.3), the future use of H&S by airlines is assessed in section 5.3.

Together with an increase in the number of movements at hub airports the use, on average, of small size aircraft further increases the capacity needed to serve the demand for air transport services. Considering that aircraft capable of carrying over 400 passengers, such as the B747-400, are in operation, using small aircraft can be seen as waste of runway and ATC capacity. In 2002, 136, 105, 96 and 94 passengers were carried per Air Transport Movement (ATM) at Heathrow, Frankfurt, Schiphol, and CDG (based on ACI, 2004) at a time when the airports experienced congestion. The main reason for the relatively low aircraft size is that, in the post deregulation era, service frequency became an important aspect of airline competition (Doganis, 1992). The exploitation of high frequency as a means of competition is evidence on the Amsterdam - London route. In 1980, the route was served by three companies offering 129 flights a week and a capacity of 17,302 seats, an average aircraft size of 134 seats. During 1984-5 the route was opened to free competition, and in 1997 six companies operated on the route offering 314 flights a week and capacity of 41,315 seats, meaning aircraft average size has decreased slightly to 131.5 seats when congestion at airports in London and Amsterdam was already high (Uittenbogaart, 1997).

⁴ ‘Transfer passengers’ is the term used in this research.

Other than the competition effect on aircraft size, adopting H&S operation also contributes to the use of relatively small aircraft at hub airports. Airlines that operate a H&S system rely on feeder services to fully exploit the H&S system, and this traffic often originates from small airports that do not have enough passengers to allow the use of large aircraft. This traffic is often carried by the regional airlines that in 1999 offered, within Europe, an average capacity of 67 seats per flight. Those seats were only 56.2% filled with passengers (ERA, 2000)⁵. In recent years, the rise in the low-cost airline sector, which uses almost exclusively narrow-body aircraft (Doganis, 2001), further contributes to the low size of the aircraft fleet.

The obvious reason for congestion in the ATI seems to be the lack of supply of infrastructure to meet the increase in demand for air services. However, the ATI way of operation in the post deregulation era, and mainly the adoption of H&S operation together with increase service frequency and the use of smaller aircraft, is certainly exacerbating the problem. Even more so, it might actually cause the problem.

The main outcome of congestion is delays to air services, in other words “congestion expresses itself in delay” (Caves and Gosling, 1999: 60). An analysis of delays to air services in Europe is described in Appendix A. The picture which emerges from it is one of severe disruption to services, which has implications for passengers, airlines, airports and the environment.

2.1.2 The ATI impact on the environment

With the growth of air services and with the advances in research, it became apparent that air transport services have an adverse effect on the environment. The ATI operation is associated with emission of different gases that cause health problems and increased mortality according to research and the World Health Organisation (Maddison, 1996; Whitelegg et al, 2001; RCEP, 2002)⁶. The main environmental effects of the ATI can be divided into three groups: global warming (also referred to as climate change), Local Air Pollution (LAP), and noise. Except for climate change, the effect is of local magnitude, but since most major airports are located in or close to densely populated areas, many people are affected.

Noise pollution from aircraft operation is the environmental impact that receives most public attention. This can be attributed to the number of people directly affected, often on a daily basis, by noise from aircraft operation. Those people live near airports and under the flight

⁵ See also Graham, 1997.

⁶ See also section 3.4 for more references.

path of aircraft approaching or leaving the airport. The recognition that noise generated by aircraft is a problem and an annoyance to people affected by it, together with the rapid growth of aviation, led the ICAO to introduce noise standards with the specific purpose of controlling noise at source. Noise standards concern the airport's operation hours as well as the types of aircraft allowed to use it. At some airports, flight curfews are imposed throughout the night and most airports have restrictions on the operation of aircraft during the night.

These noise standards are being updated and made stricter with time, leading to the development of significantly quieter aircraft. However, this does not necessarily lead to reduction in noise pollution with time. The main reasons are as follow. First, an increase in aircraft traffic results in the balance of nuisance shifting from the disturbance caused by each aircraft to the frequency with which people are overflowed (Thomas and Lever, 2003). Second, an increase in environmental awareness and the emerging notion of sustainability lead to the recognition that noise is a form of pollution, that people have the right to quiet, and that the industry standards are not appropriate. The latter is evident in the many campaign groups which set themselves the task of limiting the operation and expansion of the ATI, mainly on the basis of noise pollution⁷. Another reason for the increase in noise pollution is the relatively slow phasing-out of older, and noisier, aircraft which means the new, and quieter, aircraft form a relatively small part of the world commercial aircraft fleet. With the increase in aircraft traffic forecasted, noise pollution is bound to increase.

Compared to noise, aircraft operation impact on climate change is a relatively new, but an increasing, concern. Emissions from aircraft operations are a growing contributor to climate change (DETR, 2000a), and aviation is believed to contribute to climate change even more than its share of emission of Green House Gases (GHGs) in the total anthropogenic GHG emissions. This is due to the height at which most of the emission occurs. "The total radiative forcing⁸ due to aviation is probably some three times that due to the carbon dioxide emissions alone. This contrasts with factors generally in the range 1-1.5 for most other human activities" (RCEP, 2002: 37). It is mainly this characteristic that led the Intergovernmental Panel on Climate Change (IPCC) to devote a special report to the way the aviation industry affects the global atmosphere (IPCC, 1999). In 2000, the UK civil

⁷ The Heathrow Association for the Control of Aircraft Noise (HACAN) that campaigns for noise reduction from aircraft operation in the surroundings of Heathrow airport is one example (see HACAN, 2002).

⁸ Radiative forcing is "a measure of the importance of a potential climate change mechanism. It expresses the perturbation or change to the energy balance of the Earth-atmosphere system in watts per square meter (Wm⁻²). Positive values of radiative forcing imply a net warming, while negative values imply cooling" (IPCC, 1999: 3).

passenger aviation produced 5% (30 million tonnes) of UK CO₂ emissions from all sectors, and this is estimated to grow to about 10-12% (55 million tonnes) in 2020 (DfT and HM Treasury, 2003). In addition, it is recognised that emissions of NO_x from aircraft operation at high altitude, although relatively small in quantity, contribute as much, and maybe even more, to climate change as emission of CO₂ (Archer, 1993, IPCC, 1999). Another impact on climate change specific to aircraft operation is the formation of contrails and cirrus clouds from aircraft flying at high altitude, but the scale of the effect is still uncertain (IPCC, 1999).

LAP from aircraft operations usually receives less attention than noise and climate change impacts but it is as much of a concern. "Research in the USA shows that airports rank with chemical factories, oil refineries, and power stations among the top four emitters of nitrogen oxides and VOCs [Volatile Organic Compounds]" (Whitelegg et al, 2001: 14). However, the increase in LAP around airports is not only the result of emission from aircraft. Other sources of emission are the extensive supply and maintenance of equipment and facilities that provide for the aircraft on the ground; the fuel lines and refuelling facilities from which there is significant evaporation of VOCs; and the heavy road traffic generated by airports' employees, travellers, and visitors (ibid). According to the DETR "the effect of emissions from aircraft on air pollution in the vicinity of airports is, in most cases, less than that of emissions from road traffic to and from airports" (DETR, 2000a; 40). The scale of aviation's impact on LAP can be realized by the fact that costs associated with health problems caused by air pollution from the UK aviation sector are estimated at more than £1.3 billion a year (Whitelegg et al, 2001). Furthermore, Heathrow alone contributes about 10% of the total VOC of England and Wales (Button, 1993).

There are other environmental impacts associated with the operation of the ATI. These are related to townscape, landscape, biodiversity, heritage, and water (DETR, 2000b), but they are considered to be of less significance compared to noise, LAP, and climate change impacts. Nevertheless, these effects are significant in most cases. For example, the proposal to build a third, 2000m long, 'short' runway at Heathrow will result in an increase of the airport area from 12 km² to about 14 km²; the demolition of around 260 residential properties, and the reclamation of 230ha agricultural land, all within the London Green Belt⁹. In terms of heritage, the construction of the runway might have an impact on a grade I listed building, which is also classified as a Scheduled Ancient Monument, one church, eight grade

⁹ "The fundamental aim of Green Belt policy is to prevent urban sprawl by keeping land permanently open" (ODPM, 2001: 1.4). In the case of Heathrow Terminal 5 (T5), a development within the green belt, planning permission was granted only since special circumstances existed which justified it (Vandermeer, 2001).

II listed buildings and 25% of a conservation area will be lost (DFT, 2003a). This is in addition to the environmental impact associated with increased emission.

The trend of increasing environmental impact from the ATI is likely to continue in the future despite technological improvements that resulted in reduction of the environmental impact of a given flight. “The air transport industry is growing faster than we are currently producing and introducing technological and operational advances which reduce the environmental impact at source” (CEC, 1999: i). The IPCC reached the same conclusion, stating that, “although improvements in aircraft and engine technology and in the efficiency of the air traffic system will bring environmental benefits, these will not fully offset the effects of the increased emissions resulting from the projected growth in aviation” (IPCC, 1999: 11). On the same issue, the Royal Commission on Environmental Pollution (RCEP) concludes: “the ambitious targets for technological improvements in some industry announcements are clearly aspirations rather projections; IPCC’s projections are already optimistic” (RCEP, 2002: 37).

It is apparent that the ATI operation has an adverse impact on the environment (this is further demonstrated in sections 3.4 and 4.3), which affects the entire society. From the ATI perspective, this impact becomes a problem once it has to address it and take account of it. This is the case in recent years and it seems certain to be even more so in the future. Currently noise restrictions exist in almost all major airports (Schiphol airport, for example, has reached its ‘noise capacity’ before having made full use of its runway and terminal capacity (Thomas and Lever, 2003)), and from 2010, Governments will be obliged to ensure that critical sites are not exposed to an excess of certain NO₂ and PM₁₀ limits (DETR, 2003b). Furthermore, there is an increasing pressure to make the ATI limit this impact or fully pay for the damage it causes through Kerosene tax, emissions tax, etc. (CfIT, 2003; Environmental Audit Committee, 2003; DfT and HM Treasury 2003). The practices adopted by airlines after the liberalization of the air transport market, which contribute to the congestion problem, increase the environmental impact imposed by the ATI (Graham and Guyer, 1999). The environmental impact from the ATI operation is a problem caused by the industry, and it is increasingly becoming a problem for the industry.

2.1.3 The socio-economic benefits of the ATI

Apparently, there is one solution to deal with both the problems of congestion and environmental damage and that is to limit the supply of air services. However, the operation of the ATI has an economic and social importance that brings benefits to society, and these would be lost if air services were limited.

In theoretical terms, the benefits from the ATI operation are apparent from the existence of demand for air services. Demand for transport is considered a derived demand, i.e. most people would prefer not to fly in order to undertake a desired activity (like a business meeting or holiday) and they will do so only when the benefits of the activity outweigh the costs of flying (travelling)¹⁰. Therefore, the actual demand for air services, 538 million passengers in 1998 (ATAG, 2000), is evidence of the benefits brought by the ATI operation (Caves and Gosling, 1999). In empirical terms, the economic benefits of the ATI are considered to be job creation (direct, indirect, and induced¹¹), high productivity compared to other industries, support for the tourism industry, and attraction of inward investment (OEF, 1999). The social benefits from the ATI operation are accessibility to isolated, far away, and/or overseas communities where road and rail transport is limited, and improved accessibility to places where journey by road, rail and sea transport is too slow.

In the US, the commercial aviation sector contributes over \$800 billion, which is 8% of US GDP, and 10 million jobs (Air Transport Association, 2003). In the UK, a study called “The contribution of the aviation industry to the UK Economy” (OEF, 1999) estimated that the industry is responsible for 1.4% of UK GDP. It calculated that the aviation industry directly generates 180,000 jobs in the UK, a further 200,000 jobs depend indirectly on the aviation industry, and another 100,000 are ‘induced’ by the aviation industry activity. The study illustrates the importance of meeting the forecast demand for air services with a supply of new infrastructure by estimating that “a 25 million a year reduction in the number of passengers...would mean that GDP would be expected to be nearly £4 billion a year (in 1998 prices) lower by 2015” (OEF, 1999: 5).

The above figures might be an overestimation since they represent the view of the industry¹². In addition, the OEF study was criticised for overestimating the benefits brought to the economy by the ATI (e.g. Grayling, 2001; Grayling and Bishop 2001; Sewill, 2003) and mainly for relying on “unproven assumptions about the link between aviation and productivity growth and further assumptions about the effects of growth constraints that exaggerate the effects on economic growth” (Grayling, 2001: 8). The 1999 Standing Advisory Committee on Trunk Road Assessment (SACTRA) study on transport and the

¹⁰ Recent research contests the assumption that travelling always has negative utility and that demand for travel is always derived demand (for example, Mokhtarian and Salomon, 2001). Perhaps leisure air travel is most likely to be the case where the assumption does not hold given the excitement from flying some people have, especially in comparison to travelling by other modes.

¹¹ Direct – jobs in firms inside the ATI; in-direct – jobs in firms outside the ATI that exist because they supply goods and services to the ATI; induced – jobs created through the ATI use of its income for consumption (OEF, 1999). See also Banister and Berechman (2000: 289)

¹² The OEF study was commissioned by a consortium of major UK airports and airlines and the government.

economy questioned the link between transport investment and economic growth and commented that “in the case of well-developed economies, such as the UK, doubts are raised as to whether even significant programmes of transport investment can have anything more than marginal impact on national GDP” (SACTRA, 1999: 50)¹³. The RCEP agrees with SACTRA observations and concludes that “in any case the resources displaced by restrictions on air transport would find other uses in due course, probably with similar or only slightly lower market value and [would be] much less damaging environmentally” (RCEP, 2002: 6).

In addition, critiques claim that since the prices passengers pay to fly do not represent the true costs of flying (mainly due to different tax exemptions and exemptions from meeting the cost of environmental damage caused by flights), demand is artificially high (Sewill, 2003). Thus, apparent demand is not evidence for the level of net benefits. Sewill (ibid) estimates that if the ATI paid fuel taxes, including VAT, and duty free was abolished, the number of passengers using UK airports in 2030 would be 315 million, compared to the 500 million estimate of the DfT.

However, even those opposing any expansion of airports to meet the forecast demand and to relieve congestion, recognise the contribution of the industry to the economy, and its social importance, and do not recommend stopping the ATI operation. Instead, they argue that the contribution of the ATI is often overestimated and that many fail to properly address the environmental pollution caused by it. Specifically, they urge policy makers to reconcile “the economic and social benefits of air transport growth in trade, travel and employment with the economic, social and environmental costs, including congestion, noise, air pollution and use of natural resources” (Grayling and Bishop, 2001: 5).

Governments traditionally see the ATI as an important national and regional economic driver¹⁴, and based on that, tend to support the expansion of the ATI operation, and in other cases secure the operation of air services through Public Service Obligation (PSO)¹⁵.

2.1.4 Forecasts for growth in demand for air services and their implications

The extent to which the conflict between securing the social economic benefits provided by the ATI and the need to reduce its environmental impact will continue in the future depends

¹³ The same notion is apparent in Banister and Berechman (2000).

¹⁴ For many years this was one of the rationales to justify state ownership of airlines (Staniland, 2003).

¹⁵ See section 5.2 for the UK Government view of the ATI.

mainly on the growth in demand for air transport services and the pressure it will create to supply additional airports and runways. During the past four decades, aviation has experienced the highest growth rates of all modes of transport, from 551 billion passenger kilometres in 1970 to 2,537 billion in 1995, an annual growth rate of 6.3% (Whitelegg et al, 2001). Aviation is also predicted to experience the highest growth rates of all modes in the future, and in 2050 is forecast to provide 36% of the global mobility, compared with 42% share for the car, or 28 times its level in 1990¹⁶ (Schafer and Victor, 2000). Boeing and Airbus, the two leading aircraft manufacturers, each year produce a 20 year forecast for the growth in demand to air services. In 2004, Boeing forecast an average 5.2% yearly increase in passenger traffic (Boeing, 2004). In 2003, Airbus predicted a 5.0% annual increase in revenue passenger kilometres (RPK) for the next 20 years (Airbus, 2003). Both companies are confident that demand for air services will continue to be linked with economic growth, and will outpace the growth in GDP for that period.

Between 2001 and 2002, the ATI was in a downturn cycle in which passenger traffic was in decline (2001 and 2002 traffic compared to 2000). This cycle began modestly in early 2001 with the bursting of the high-technology market, but turned into a severe crisis to the industry after the 11 September terrorist attacks (Boeing, 2003a)¹⁷. These attacks raised speculation that the ATI will not continue its high growth rates of the past and that forecasts must be updated to reflect this. However, in 2003, despite the continued fall in traffic due to the war in Iraq and the outbreak of the SARS virus¹⁸ (in May 2003 world traffic was 21% lower than, an already relatively low, May 2002 traffic) the ICAO forecast that recovery would get fully under way in 2004 and 2005 (AirWise News, 2003d) and this is apparent in the recent forecasts by Boeing and Airbus.

The above estimates, although considered to be a good benchmark across the industry, are industry based and might be positively biased. However, other forecasts are not much different. In 2000, the DETR published a forecast for air traffic in the UK until year 2020. According to the DETR, traffic to, from and within the UK will amount to over 400 million passengers in the year 2020 (medium scenario) compared with about 160 million in 1998, an annual growth rate of 4.3% (DETR, 2000c; Figure 4)¹⁹. The IPCC forecast average growth in RPK for the years 1990-2050 to be between 2.2% (low growth scenario) to 4.7% (high

¹⁶ The last estimate refers to 'high speed' mobility which include HST (and MAGLEV) and aircraft.

¹⁷ See also Nolan et al (2004) and Air Transport Association (2003).

¹⁸ SARS – Severe Acute Respiratory Syndrome – a deadly flu-like virus which emerged in China, killed around 800 people, and forced airlines to stop their flights to the infected areas in a bid to stop the disease from spreading around the world. In addition, fear of flying due to SARS further resulted in reduction of services around the world.

¹⁹ The 2003 aviation White Paper (DfT, 2003b) is based on the same forecast.

traffic growth) (IPCC, 1999). So overall there seems to be consensus that the ATI will continue to grow for the foreseeable future with a relatively high rate.

Figure 4: Actual and forecast passenger numbers at UK airports, 1975 to 2020

Image removed due to third party copyright

Source: DTLR (2000c).

Almost all forecasts of demand for air services are based on the linkage between economic growth and demand for air services. “Since income elasticities of air travel and air cargo are high, the world’s demand for air transport grows nearly twice as fast as the world’s GDP growth” (Oum et al, 2000; 1). Although this linkage existed in the past, it does not necessarily have to continue into the future, especially in developed economies. Changes in the air travel industry, and especially the reduction in fares over the years, have resulted in an increase in market penetration that has contributed to increase in demand. As the market matures, past growth in demand is unlikely to continue (Graham, 2000). However, the success of the low cost airlines in Europe and the rapid expansion of their networks and increase in traffic might suggest that the market has not yet reached maturity.

The forecasts presented above measure the unconstrained demand for air services. However, if new capacity is not supplied, the demand will not materialise into actual traffic. The DfT estimated that its proposals in the White Paper, if materialized, would provide capacity which is 30 million passengers short of the unconstrained forecast of 500 million passengers in 2030 (DfT, 2003b). The slow rate in which capacity is provided, and the uncertainty in its provision, suggest that the gap between capacity and demand is likely to be greater.

Considering that decoupling transport growth from the growth in GDP is one of the main objectives in the EC's recent communication on sustainable development, and in its transport White Paper (Stead, 2001), the future linkage between demand for air services and economic growth in the long term should not be taken for granted. If the EC's objectives are met, then trends in GDP can no longer be used to estimate demand for air transport services. Under the above circumstances, "airport capacity seems set to become the decisive factor affecting the growth of civil aviation in Europe" (ECAC/EU, 1999; 1).

Despite the pressure against providing more capacity, whether from the EU or environmental groups, it seems likely that the industry will continue to experience growth in the future. Even when considering the natural limitations of forecasting, it seems unlikely that the growth in demand for air services will stop or decline in the near future. This means that the congestion problem is likely to intensify, resulting in an increase in delays and in environmental impact from the ATI operation.

The likely increased capacity constrain and delays to services at major hub airports require a response from airlines and changes to their operating strategy. The two main options for the airlines seem to be to increase the size of aircraft operating through hub airports²⁰, and increase the number of point-to-point services which bypass the congested hub airports. Boeing and Airbus seem to differ in their forecast as to which strategy will be preferred by the airlines. Airbus is developing the Airbus A380, which will be capable of carrying more than 800 passengers (AirWise, 2004c)²¹ as their response to the first strategy; it is a "solution to growth in air transport between major hubs" (Airbus, 2002b: 8). In its forecast, Airbus predicts that "airlines will have to increase the average number of seats installed in each aircraft by 1% per year, to 219...in 2020 from 180 in 2000" (Airbus, 2002a: 28). Boeing believes that it is the other strategy that the airlines will choose (i.e. point-to-point routes that will by-pass the hubs). It forecasts that "passengers require more frequent non-stop service to more city pairs" (Boeing, 2002: 3). As a result, Boeing announced the development of the high speed airplane, the Sonic Cruiser, to provide the speed to cut travel time not only by providing direct services but also through faster aircraft. Boeing also predicts, contrary to Airbus, that "these network strategies [of point-to-point services rather than H&S] generally demand that airlines maintain or **reduce airplane size** to provide frequent non-stop service" (ibid: 15 my emphasis). Although Boeing halted the development of the Sonic Cruiser at the beginning of 2003 (AirWise News, 2003a), they remain confident in their prediction and are now developing the Boeing 7E7 Dreamliner. The 7E7, expected to enter service in 2008, will

²⁰ An increase in capacity without extra runway capacity.

²¹ Airbus states that the capacity of the A380 is 555 passengers, but in three classes layout (Airbus, 2002b).

enable airlines to use mid-size aircraft (200-250 seats) on long distance routes currently served by big-size aircraft (Boeing, 2003b)²². There is a possibility that both manufacturers, Boeing and Airbus, are right²³.

2.1.5 HST as a solution to the problems faced by the ATI

Congestion at major international airports limits the operation of the ATI and the apparent impact of the ATI on the environment threatens to limit it further. These limitations directly affect the airlines and the passengers. Indirectly they affect society by constraining the social-economic benefits from the ATI operation.

Solutions to solve or at least alleviate the problems faced by the ATI mainly focus on the congestion rather than the environmental problem. These solutions can be divided into three categories. One is providing more infrastructure to accommodate growth in traffic, the second is to use technological developments to increase the capacity of the air transport system (mainly through improvements in the ATC system), and the third is to increase capacity through adopting different policies (such as increasing use of secondary airports).

When considering the different options, it is important to remember that capacity constraint in the ATI exists in both the runway and the ATC components of the system. This means that building more runways without providing more ATC system capacity (and vice versa) is not likely to relieve congestion in the long term. In addition, any solution that results in an increase of aircraft movements will, inevitably, result in increased environmental impact from the ATI operation.

Using HST services to substitute some aircraft services can offer a 'reconciliation' between the economic and social benefits and the social and environmental costs that result from the ATI operation. The HST operation is believed to result in less environmental damage than aircraft operation (e.g.: Viegas and Blum, 1993; EC, 1996; Maddisson et al, 1996; Caves and Gosling, 1999; IPCC, 1999; AEF, 2000; Whitelegg et al, 2001; RCEP, 2002; and Janić 2003a+b), and therefore any demand for air services that is met through HST services and not aircraft services will lead to a reduction in the environmental damage imposed by the ATI. The fact that demand is met, and not rejected, means that the social-economic contributions from the ATI operation are not lost. Furthermore, HST operation provides an increase in airport capacity without extra runways or ATC capacity and it releases capacity in these components when traffic is diverted from the aircraft to the HST. In addition,

²² The use of aircraft such as the Boeing 777 on long-haul routes, where it replaces the larger Boeing 747-400 is probably the beginning of such a trend.

²³ See section 5.3.3.

providing HST services at airports also relieves access congestion by providing fast, high capacity public transport services. Hence, it reduces the environmental impact from the trips to and from the airport mostly made by private car.

Replacing aircraft services with HST services can be the means to achieve sustainable development of the ATI, a target set, for example, by the EU (CEC, 2001) and the UK Government (DETR, 2000a). In its 2001 transport White Paper, the EU calls for co-operation between air and rail modes and states that “network planning should therefore seek to take advantage of the ability of high speed trains to replace air transport and encourage rail companies, airlines and airport managers **not just to compete, but also to cooperate.**” (CEC, 2001: 53, emphasis in original text). Furthermore, the White Paper states that “we can no longer think of maintaining air links to destinations for where there is a competitive high speed rail alternative” (ibid: 38).

2.1.6 Conclusions

The story of the ATI in the last few decades is one of success, as is apparent from the industry’s impressive growth rate over that period. However, this success has brought with it problems that disrupt the ATI’s present operation and are likely to impede the growth of the industry in the future. The problems are mainly of congestion and the increased environmental pollution that is directly linked to the ATI operation.

The problem of congestion, which is the result of insufficient supply of infrastructure to meet present demand, leads to delays in air services. To some extent, the congestion problem is attributed to the airlines’ way of operation in a deregulated market, and specifically to the adoption of H&S operation. The problem of increasing environmental impact inflicted on society through the ATI operation becomes more apparent as the industry grows, but also as research and understanding of the problem progress. In view of the forecasts for growth in demand for air services in the future, there is general agreement that those problems and their implications are likely to intensify.

Solutions in the form of providing more infrastructure address the congestion problem only, and calls to limit the ATI level of operation, in order to reduce the environmental damage it causes, overlook the benefits brought to society by the ATI operation. However, the use of HST to substitute the aircraft on some routes addresses both problems.

The substitution of some short haul aircraft services with HST services is believed by many to lead to reduced environmental damage from the ATI operation and at the same time can relieve congestion since it frees runway and ATC capacity. Furthermore, substitution of

aircraft with HST is expected to result in other direct and indirect benefits, for example improved access to airports and delay in the need to invest in new runways.

This solution to the problems faced by the ATI is the subject of this research. It aims to evaluate the benefits, to different stakeholders, from a specific way of mode substitution, one that leads to airline and railway integration. The properties of such substitution are discussed in section 2.3. The development of the HST, which is paramount for aircraft and HST substitution, is discussed next.

2.2. The development of the HST

Transport technologies seldom make a comeback, save in nostalgia trips for well-heeled tourists. Stagecoaches have not made a reappearance on the Bath road, nor sedan chairs on the streets of London. But there is a spectacular exception: railways, written off thirty years ago as a Victorian anachronism destined to atrophy before the steady growth of motorway traffic, have suddenly become one of the basic technologies of the twenty-first century.

The reason of course is the high speed train

(Banister and Hall, 1993: 157).

On October 1, 1964 the first HST passenger service, on the 560 km Tokaido line between Tokyo and Osaka, was launched with trains running at speeds of 210 kph. This date marks the beginning of the modern HST era. Since then the network of HST has expanded, first in Japan, and later in other countries, and the speed has increased.

It is the development of the HST which makes the train a viable alternative to the aircraft on some short haul, in aircraft terms, journeys. The HST becomes an even more attractive substitute to the aircraft when considering the problems faced by the ATI to which the HST can provide some solutions. Appendix B illustrates in detail the development of the HST and how it evolved to be the main competitor to the aircraft on some routes, and potentially a replacement to airlines' aircraft services on some routes.

The main reason behind the construction of HST lines is to increase capacity on the route. At least this was the main reason behind the first Shinkansen and TGV lines²⁴, and the lack of similar projects in the UK²⁵. In both cases the expansion of the conventional existing line was considered, but was regarded as inferior solution to the HST option. Nevertheless, the ability of the HST to compete successfully with the aircraft was not overlooked. The 270 kph speed for the TGV was decided based on studies which showed that at lower speeds "the system would not be competitive with the aircraft" (Bouley, 1994: 57). It can be concluded that the HST was developed as an incremental, yet relatively big, advances in conventional railways at the time in order to substantially increase capacity and improve the service by reducing travel time. Consequently, the railways reached the point where trains would be a good substitute to the aircraft on some routes, and this became another, certainly not the main, reason for the construction of HST lines.

²⁴ See Shima (1994) for the Shinkansen and Bouley (1986) for the TGV.

²⁵ See CfIT, 2004.

The ability of HST services to offer high capacity and fast services means that HST competitiveness is a factor of the route distance and demand for services. Perhaps surprisingly, it is the level of demand which seems more important in determining HST service competitiveness. When demand is low, there will usually be no justification for HST line. However, when demand is high the HST option will be competitive on routes ranging from a few tens kilometres to a few hundreds. Short-distance HST services are usually city-centre to airport rail services, or services between intermediate stops along a HST line. On long-distance HST services, the HST competes with the aircraft²⁶.

Generally, a HST line is considered to be commercially viable “between major urban agglomerations, with over one million population...[when] such agglomerations are disposed along linear corridors, with cities spaced at approximately 125-mile (200km) intervals” (Hall, 1999: 6-7). The Tokaido Shinkansen line between Tokyo and Osaka follows these characteristics, but it consists of 17 stops²⁷, which means the average distance between stops is only 30km²⁸.

The necessity for high demand to make HST services competitive is why most HST services will be between city-centres. Hence, cities with dense and dominant city centres (in terms of population and/or employment) are more attractive for HST services. In contrast, large cities which are more dispersed in nature will be less attractive to HST services, since the long access journey to the HST station might cancel the time savings from the HST service. However, in large cities which are polycentric (rather than monocentric) in nature, more than one HST station can be built. Tokyo, for example, has three stations on the Tokaido line including: Tokyo, Shinagawa, and Shin-Yokohama stations, thus reducing the average access distance (and time) to the HST service. The fact that a HST service can ‘collect’ passengers at more than one location within a city is a great advantage over the aircraft (or airport), since it reduces average access distance (Hall, 1999). However, this is justified for the HST only when demand is very high.

Predominantly, HST services are considered on city pair routes. However, with the increase in construction of HST lines, a network of HST lines emerges. In Europe, this network, which is promoted through the TEN-T projects, has an international dimension that increases the scope for HST services, since many countries do not have domestic routes which can

²⁶ See section 2.3.2.

²⁷ Including Tokyo “Shinagawa station” opened in 2003, 7 km from Tokyo HST station.

²⁸ The Kodama service, which serves all the stops between Tokyo and Osaka at a maximum operating speed of 220 kph is according to the EU definitions a HST service. The express service on this line, the Nozomi (maximum operating speed 270 kph), stops at Shin-Yokohama and Tokyo stations (29km apart), and at Kyoto and Shin-Osaka stations (39km) (Central Japan Railway Company, 2003).

justify HST services. This also increases the scope for mode substitution. Because the HST network is better integrated with the conventional rail network than the network of airports, HST services can offer passengers easier access to many more destinations within a country than an aircraft service to that country.

The scope for substitution of aircraft by HST depends on the expansion of the HST network. The expansion of the network depends first on the existence of (very) high demand on the route, and second on the success of the HST in serving this demand better than competing modes. At present, evidence suggests, HST lines cannot be justified based on their impact on economic development (see Appendix B3).

From the passenger standpoint the attractiveness of the HST service, in general and as a substitute for the aircraft, depends mainly on the journey time it can provide from origin to destination. Thus, in this research, average journey speed is more important than maximum journey speed (although the latter influences the former) and, therefore, in this research the definition of a HST, in terms of speed, is of less importance.

For several reasons, Europe makes a good case for aircraft and HST substitution. The main reasons include the plans for the European HST network (important parts of which are already completed), and the current capacity shortage faced by the ATI. The dominance of H&S operation in most of the heavily congested airports further increases the potential for aircraft and HST substitution²⁹, but through cooperation and not competition, between the modes. Appendix B2.1 describes the development of the European HST network.

The different forms of relationship between the aircraft and the HST modes, one of which is integration, are explored and discussed in the next section.

²⁹ See section 2.3.3.

2.3 Substitution and complementarity between aircraft and HST

Trains and aircraft can be both substitutes and complementary modes. According to the COST 318 study on the interaction between high speed and air passenger transport, “two modes of transport will be regarded as complementary for the user when their successive utilisation is either necessary or simply preferred to the utilisation of a single transport mode for a journey between two cities” (EC, 1998: 118). Accordingly, two modes of transport will be regarded as substitutes for each other when the user can utilise only one of them for a journey between two cities. When each mode is operated by a different operator, it can be further defined that when the modes are substitutes competition between them will result, while when the two modes are complementary, no competition will occur and possibly cooperation will take place.

The COST 318 Action on the interaction between high speed and air passenger transport begins by stating that the following theses are proved and do not need to be further investigated:

- *High speed rail traffic can successfully compete with air traffic*
- *Air traffic, on the other hand, has good possibilities of being developed where the demand is not too high.*
- *Within the framework of a system of high speed travel rail and air traffic can complement each other well; usually they are also competitors.*
- *Attractive rail connections at airports allow access costs to be minimised with respect to both waiting time and external costs (safety, air pollution etc.)*

(EC, 1996: 5).

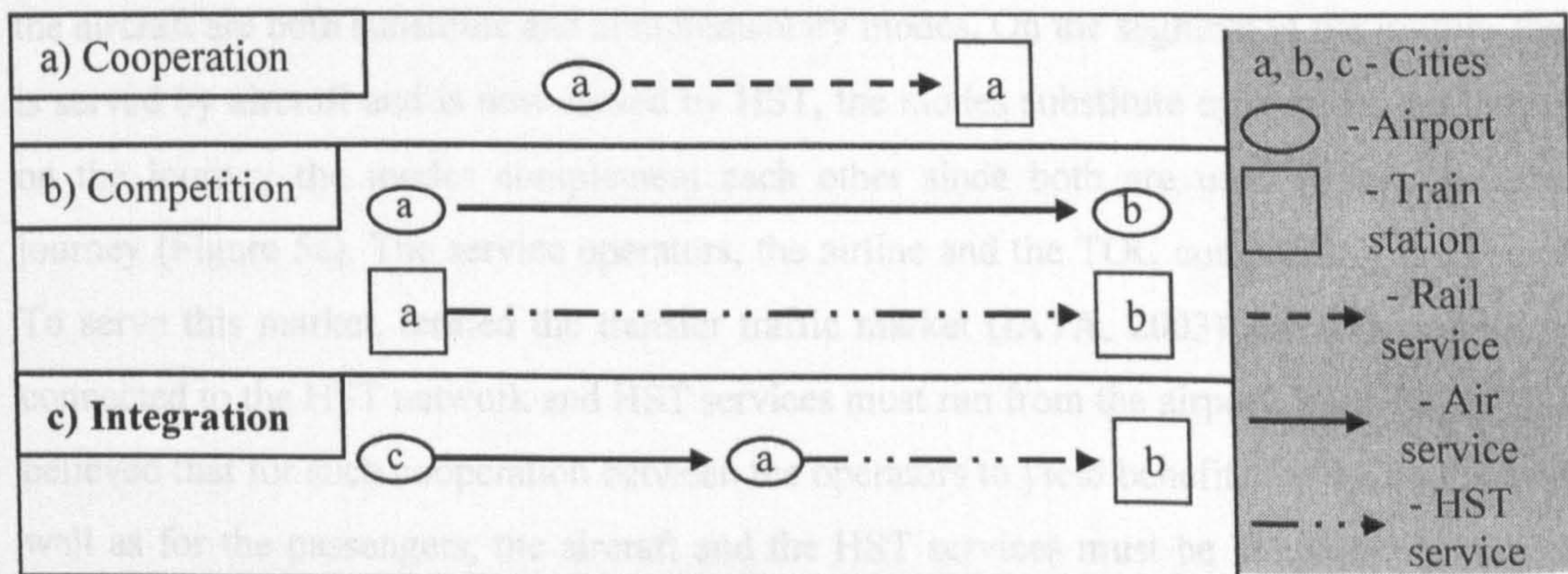
This research accepts these statements. The statements also support the division of the interaction between air and rail services into three definitions based on the market served, the relationship between the modes (substitution or complementary), and the mode operator. Table 1 (and Figure 5) summarise and outline the division of interactions between air and rail services into: cooperation, competition, and integration, based on the relationships between the TOC and the airlines, and the way the (airline) passenger uses the train in relation to using the aircraft.

Airports are usually located at the outskirts of cities, and rail services are often used as a mode to access³⁰ the airport. In this case, the two modes are complementary, and both need to be used in order to arrive from origin to destination. The rail service is also complementary to the aircraft service from the service operators, the airline and the TOC point of view. This kind of relationship between the modes is termed cooperation because each mode is contributing and feeding traffic into the other, benefiting both the passenger and the operators, and suggesting cooperation between the modes. However, actual cooperation will not usually take place between the mode operators, as it is more likely for cooperation to take place between the TOC and the airport operator. This way of using the train in the ATI can take several forms, the most common of which is a service to the city centre (Figure 5a), for example the Heathrow Express service from Heathrow to Paddington in central London. Other forms are detailed below (section 2.3.1).

Table 1: Typology of relationships between rail and air service operators

	Market (city)	Relationships between air and rail		Rail link to Airport?
		Modes	Operators	
Cooperation	Airport (a) - city centre (a)	Complementary	Complementary	YES
Competition	City centre (a) - city centre (b)	Substitution	Substitution	NO
Integration	Airport (a) - city centre (b)	Substitution / Complementary	Complementary	YES

Figure 5: Typology of relationships between rail and air service operators



The advent of the HST made it possible for the rail to substitute the aircraft on some routes, leading primarily to competition between the modes. On routes of up to around 800 km or one hour flight, HST services can offer the same or shorter travel times, city centre to city centre, and thus can replace the aircraft, as the evidence shows³¹. In this market, the city centre to city centre, also referred to as point-to-point market (IATA, 2003), the modes are substitutes for each other since passengers will use the aircraft or the HST (Figure 5b).

³⁰ The use of the term 'access' in this section equally means 'egress'.

³¹ See Appendix B.

Because each mode is operated by a different operator, the TOC service (the rail service) is a substitute for the airline (aircraft) service³² leading, inevitably, to competition between the modes and between the service providers. In this market, when the passengers choose the HST they do not pass through the airport on their journey and there is no need for a railway link to the airport. Such competition is currently taking place on the Paris-London route, where passengers can choose to fly between Heathrow and CDG or use the HST between Waterloo and Gare-du-Nord. The aspect of competition between the modes is further discussed in section 2.3.2.

H&S operation by airlines means that two flights are used in conjunction within one journey. The first flight arrives at a hub airport and the second one departs from the hub airport. This way of operation, favoured by many airlines, often involves a long and a short haul flight. In some cases, the short haul flight can be operated by HST instead of aircraft, creating an opportunity for mode substitution in which operators cooperate and do not compete. Considering the congestion problem at major hub airports, as well as the environmental problem that can limit airline operations, it may be beneficial to airlines to substitute the short-haul flight with HST as long as the airline continues to be the service provider, and thus retain the passengers and (some of) the revenues. Such mode substitution can potentially bring many benefits to the airline. However, the complexity for an airline to start offering HST services suggests that cooperation with the TOC is more likely. In this case, when the TOC is operating the service provided by the airline to its passengers, the HST and the aircraft are both substitute and complementary modes. On the segment of the journey that is served by aircraft and is now served by HST, the modes substitute each other, but overall on the journey the modes complement each other since both are used within the same journey (Figure 5c). The service operators, the airline and the TOC complement each other. To serve this market, termed the transfer traffic market (IATA, 2003), the airport must be connected to the HST network and HST services must run from the airport. Furthermore, it is believed that for such cooperation between the operators to yield benefits for the operators as well as for the passengers, the aircraft and the HST services must be integrated to provide one seamless journey for the passenger, hence **airline and railway integration**. A service from New York to Paris via Heathrow, where the airline offers a flight to Heathrow and then a HST journey from Heathrow to Paris (which is operated by the TOC and not the airline) is an example of a service on such market (further discussed in section 2.3.3). This market, and this way of operation, is the focus of this research.

³² No route was found in which rail and aircraft services are operated on the same route by the same service provider. However, the Virgin group in the UK owns both Virgin Atlantic Airways and Virgin Trains.

After each of the relationships between rail and air service operators is explored, the role of the airport in these relationships is discussed (section 2.3.4).

2.3.1 Cooperation between the modes

The main aim of connecting an airport to a rail service is to provide a means to access the airport, and especially a means that can offer an alternative to accessing the airport by car. The advantage of this mode as a means to access the airport is mainly twofold. First, it is a reliable and high capacity form of airport-access that is immune to the problems of road congestion. Second, it contributes to reduction in air pollution around airports, associated mainly with car journeys. Both advantages prompted the developments of rail links to airports (Buchanan and Partners, 1995; Holloway and Watson, 2001; Neufville and Odoni, 2003).

The development of rail links to airports can be compared with the development of rail links to ports. "Prior to the advent of road and air transport, the main form of transport for overseas journeys was a combination of rail and sea...[therefore] Railways were built directly into the seaports" (Stubbs and Jegede, 1998: 56). Hence, it is natural that as the ATI is growing, and many airports reach the size where there is enough demand to support rail services, the number of rail connections to airports increases. In 1998, 62 rail connections to airports existed in the world and 116 were planned. Of the existing air-rail links 40 were in Europe and 14 in North America. Of the planned links, 49 are in Europe, 32 in North America, and 22 in Asia (IARO et al, 1998).

Railways and airports can be connected in several ways. Based on the geographic coverage of the rail service from the airport, the following categorization is suggested (Table 2). The lower level consists of services that connect the airport with the city centre only. These services are usually by special trains (with special facilities for luggage) that provide fast and frequent connection to the city centre, but often at premium fares. Examples include the Arlanda Express in Stockholm, the Heathrow Express in London, and the Narita Express in Tokyo. At a higher level, the airport is connected to the city metro system, providing a wider geographical coverage but usually a lower standard of service in terms of travel time to the city centre and compatibility to cater for airport passengers (mainly in terms of luggage space). This is the most common type of rail link to airport (ibid). Examples include the London Underground connection to Heathrow (the Piccadilly line) and the connection of CDG to the RER system in Paris. After the 'city' level, the next level is the regional level where the airport is connected to the regional rail network. These connections can vary in terms of the number of destinations directly served from the airport, and accordingly the

geographic area covered by these services. Often, airports happen to be built close to rail lines and thus a connection is 'accidental', and serving the need of the airport passengers is not the station's main purpose (ibid). In addition, the demand for rail services is not high enough to make the airport station an important stop on routes passing through or near the airport. In this case, a change of train is required to access the main railway network, and the rail connection to the airport will usually be a spur, or a branch line from the main line (Stubbs and Jegede, 1998). Large airports located along a main line rail route will usually generate enough demand for rail services to become an important stop on the routes passing through the airport, in the sense that all trains will stop at this station, and many destinations could be reached by direct rail service. Gatwick rail station is an example of such a rail stop. Such services will usually provide access to the airport from the boundaries of the airport catchment area. As the area covered by rail services from the airport increases beyond the airport region and the airport typical catchment area, rail services become more than just an access mode to the airport, but rather a means for the airport to compete with other (regional) airports, and a replacement for short haul flights. Such rail connections, which will be categorized in the upper level of the geographic coverage, are described in the following sections. Major hub airports will often have more than one type of rail service.

Table 2: Categorization of rail links to airports based on geographical coverage

	Geographic coverage	Stubbs and Jegede (1998)	IARO et al (1998)	Examples for rail services/stations
1	City centre	Special line	High speed dedicated links	Heathrow Express service from Heathrow to Paddington
2	City	Metro line	Metro links	Piccadilly line service from Heathrow
3	The airport region	Spur line, Branch line	Accidental links	Manchester airport rail station Prestwick airport rail station
4	National / international	Main line	Regional links, High speed networks	Frankfurt airport to Stuttgart HST service and CDG to Brussels HST service

Source: based on Stubbs and Jegede (1998), and IARO et al (1998).

As a means to access the airport, the success of rail services, measured as the share of journeys to the airport made by rail³³, depends mainly on the travel time and reliability they offer against other means to access the airport. In addition, it is the quality of connection between the rail station and the terminal that is of importance³⁴, and not the connection between the rail journey and the flight. Therefore, "rail access to airports is becoming increasingly important for both train operators and the airport themselves" (Lythgoe and

³³ World best airports are: Oslo (rail mode share 43%), Tokyo (Narita) (36%), Geneva (35%), Zürich (34%), Munich (31%), Frankfurt (27%), Amsterdam (27%), and London (Heathrow) (25%) (TCRP, 2000).

³⁴ Including: distance, level difference (and the means to overcome it, e.g. stairs, elevators, trolleys), and information (on train services, and location of the terminal, etc.) (IARO et al, 1998).

Wardman, 2002: 125), and the airline is left out of this equation. However, this situation is changing. Increasing numbers of airlines include with their ticket some form of rail service. For example, Virgin Atlantic and Lauda Air³⁵ provide free train tickets to their first class passengers, the former on the Gatwick Express and the latter within Austria (IARO et al, 1998), and this practice is fast spreading to other airlines. Increasingly, cooperation between the TOC, airport operator, and the airline takes place in the form of check-in facilities at the train station, usually at the city centre train station (e.g. Paddington station in London). Such service significantly improves the rail service to the airport and the attractiveness of the rail as a means to access the airport. Yet, at present there is only one airport, Kuala Lumpur International Airport, with firm plans for city centre **check-out** facilities (Sharp, 2003).

By bringing passengers (and employees) to the airport, the TOC is cooperating with the airline, but actual cooperation between the TOC and the airline in this market is still limited. Providing check-in facilities at train stations and offering train tickets as part of the flight tickets are first steps towards closer cooperation between the TOC and the airlines. Such cooperation is not necessary when the rail is used to access the airport, but it is vital when the train substitutes the aircraft on a route originating at the airport (see section 2.3.3). The latter will, inevitably, lead to improved cooperation between the airline and the TOC on the access to airport market as well.

2.3.2 Competition between the modes

The current commercial speeds of HSTs make it possible for the train to successfully compete with the aircraft on some routes. In addition to speed, it is the fact that most cities' rail stations are located in the city centre, while most airports are on the cities' outskirts that gives the HST the advantage when comparing city centre to city centre travel time. Regardless of other advantages that shifting traffic from the aircraft to the HST might bring, it is the travel time feature that would determine the scale of any likely passenger shift and the level of success of mode substitution.

When HST services are introduced on inter-city routes where previously aircraft services had a significant share of the market, it immediately leads to competition between the modes. The immediate effect of this competition is a shift of passengers from the aircraft and airline services to the HST and the TOC's services. On the Paris-Lyon and Madrid-Seville routes, the introduction of a HST service resulted in a decrease of the aircraft modal share on the route of 24%, and 27% respectively (see Appendix B). On the London-Paris and London-Brussels HST services, following the opening of the Channel Tunnel, "the new trains have

³⁵ A subsidiary of Austrian Airlines, and a Star Alliance member.

captured as much of the air traffic as was expected - nearly two thirds of the combined air-rail traffic to Paris, nearly half to Brussels” (Hall, 2001: 30)³⁶.

Airlines, in general, continue to compete with the HST services even on routes where HST seems to have an advantage, and IATA concludes that the more likely situation is “for both modes to continue to compete” (IATA, 2003: 13). Even on routes such as Paris - Brussels and Tokyo-Nagoya where HST is considered to have won the competition, aircraft services are offered. SN Brussels Airlines offered flights on the Paris (CDG) – Brussels route (Brussels Airport, 2003), and both Japan Airlines and All Nippon Airways offered flights on the Tokyo (Narita) - Nagoya route (Opodo, 2003) during summer 2003. On the latter, JR Central claims to have 100% of the market share (Table 3). Yet, in both cases the capacity offered by the airline, in comparison to the HST service capacity, is insignificant. Even if airlines do not withdraw their services they must limit the services as a result of demand being shifted to the HST. This leads to reduced air traffic on dense short haul routes (Caves and Gosling, 1999). Evidence from the Madrid – Seville route shows that the frequency of flights on the route went down from 71 per week to 40 after the HST began operation (EC, 1996).

“The most important factor for the modal choice between air and high speed rail is **the total travelling time**” (EC, 1996: 48, emphasis in original text). Still, the distribution of traffic between the modes is often based on the route distance. Janić (2003a) found that the HST is dominant over the aircraft on routes up to 400 km, and that the aircraft is dominant on routes of over 1200 km. On routes between 400 and 1200 km, the modes compete. Pavaux (1994) defines 250-1000 km as the distances in which the modes compete against each other. Buchanan and Partners (1995) suggest that on routes of over 600 km, air services are likely to be more attractive. A recent study on HST in different countries concludes that HST cannot be competitive with air transport for journeys longer than approximately 800 km (CfIT, 2004).

The reliance on route distance as the factor which determines the distribution of traffic between the modes can be misleading. One reason is that the route distance which is the basis for comparison is the aerial distance between origin and destination, the distance as the crow flies, but the HST route does not usually follow the shortest path between origin and destination³⁷. In addition to route distance, travel time is influenced by the train’s speed. While the Madrid-Seville journey (471 km) takes 2h15m the Rome-Bologna journey (358

³⁶ Even more at present (see section 5.2.4.1).

³⁷ For example, the aerial distance between London and Paris is about 350 km and the train route is 495 km.

km) takes 2h33m (UIC, 2002). Finally, since airports and rail stations can be located at different parts of the city, the true travel time comparison should be city centre to city centre. As a result, it seems a route by route analysis should be preferred, but as a general estimation Janić's (2003a) approximation can be accepted.

Also, travel time is not always used as a factor to predict the distribution of traffic between the modes. In Japan, for example, on the routes from Tokyo to Okayama and Hiroshima, the journey, city-centre to city-centre, is faster when choosing the aircraft by 21 and 33 minutes respectively, yet on both routes the HST captures more than 50% of the market (Table 3). This might be attributed to the much higher frequency offered by the HST service in comparison with the aircraft services. In turn, the limit capacity at Tokyo's airports (Feldhoff, 2003) might lead the airlines to give up competing with the Shinkansen on frequencies on the above routes. The COST-318 study provides another explanation, which is also supported by Janić (2003a), and Zembri (2003). It concludes that:

High speed rail competes successfully on distances where it provides about equal or shorter total travelling time than air. When the total travelling time by high speed rail is slightly longer than by air, high speed rail can still compete successfully by offering higher comfort standards and good conditions for working on board. For travellers to accept substantially longer travelling times by rail, the total service concept (service level, comfort, price etc.) has to be considerably better than that of the airline

(EC, 1996: 48).

Table 3: Aircraft and HST competition on the Tokaido and Sanyo Shinkansen (2002)

Image removed due to third party copyright

Source: Central Japan Railway Company (2001; 2003).

Evidence suggests that HST does not fully replace air services. Not even one example could be found where the introduction of HST services resulted in closure of air services. In some cases, airlines are likely to continue their (aircraft) services even on routes where the HST has an apparent advantage over the aircraft, and even while incurring a loss, because they

require those services as feeders to their (mainly) long haul services. The importance of short haul feeder services to airlines operating a H&S strategy means that airlines are likely to continue to compete with the HST services, and this might lead to more pressure for slots³⁸ at airports as the airlines compete with the HST on frequency (Caves and Gosling, 1999).

A solution for the airlines in this situation is to cooperate with the TOCs, rather than compete with them, and to integrate the HST services with the aircraft (long haul) services as some airlines already do (e.g. AF on the Paris-Brussels route). This type of relationship between the modes is discussed next. It is important to note that when the modes compete with each other, there is no need to connect the airport to the HST network.

2.3.3 Integration between the modes

What seems certain, however, is that with air congestion becoming worse each year, the rail industry, and the major carriers, stand to gain as much through co-operation as competition

(Baker and Field, 2001 : 106).

Seasoned travellers already know that when they fly to one of Europe's smaller cities and need to change planes at Paris [or] Frankfurt...the second hop of their flight may be a train, not a plane

(Railway Age, 2001).

The introduction of HST services on inter-city routes leads, in most cases, to competition with the aircraft, and to passengers shifting from the plane to the train. This has been the general rule since the first HST was inaugurated in Japan in 1964 and in France in 1981. However, the above quotes signal a change in the relationship between the train and aircraft operators. Congestion at major airports, and the advantage HST has over the aircraft on some routes leads airlines to seek cooperation rather than competition with the TOC. Yet, for such cooperation to yield benefits to the airlines (and thus convince them to relinquish some aircraft services) and not be rejected (but favoured) by passengers, the level of cooperation required is one of full integration between the services. Hence, **airline and railway integration.**

Under a H&S model of operation, airlines strive to gather passengers from different origins (on what is termed 'feeder services') at the hub airport and then redistribute them and the local traffic (passengers originating at the hub airport) on flights from the hub airport. This

³⁸ A slot at an airport is the right to operate one take-off or landing at that airport within a fixed time period (Doganis, 2001).

allows airlines to improve the load factor, increase frequencies on routes served from the hub airport, and increase the number of destinations served from the hub airport³⁹. Under such a strategy of operation, rail services can be used as feeders of traffic to the hub airport and become spokes on the airline's route network. However, a prerequisite for this is connection of the airport to the rail network, serving more than the airport city (centre).

Airlines' rail services from the hub airport can be on routes where hitherto no aircraft services were provided by the airline, hence only complementarity between the modes takes place. And, they can be on routes where hitherto the rail (usually HST) journey was provided by aircraft. In this case, the rail substitutes the aircraft and at the same time complements it (when passengers travelling through a hub airport use the plane for one leg of the journey and the rail for the other). Accordingly, these are identified as two types of 'airline and railway integration', and only the latter is the focus of this research. In both cases of integration, however, the airline offers the services which are provided/operated by the TOC.

Increasingly, airlines use domestic rail services to enhance their services and destinations using rail to complement the aircraft (the first form of integration - complementary). The first steps for such integration were probably made in Switzerland, where well developed passenger check-in facilities at main rail stations exist (Buchanan and Partners, 1995). To begin with, this amounted more to cooperation between the TOC and the airport operator. Later it was the basis for integration between Finnair (airline) and Swiss Federal Railway SBB (TOC) services. Recently, Finnair added four new destinations to its scheduled network: Bern, Basel, Lausanne, and Luzern. These destinations are served by a Helsinki-Zürich flight and then a rail journey. For Finnair passengers, the integration of the aircraft and rail service is complete. The passenger experiences similar conditions as if the journey is by two connecting flights (international plus domestic). This means the luggage is checked-in and collected at both ends of the journey; the reservation and sale of tickets for both segments of the journey is made at the same time (through Finnair); one ticket is used for both segments of the journey; seat allocation for both segments is done by the airline; passengers can earn air-miles on the rail journey; and the rail service is designated a flight number (with the Finnair code, AY) and the destinations receive an 'airport' code (e.g. ZDH for Basel) (Finnair, 2002).

In the above example of integration, the train service does not replace the aircraft service, certainly not Finnair's aircraft service, but complements it. Thus, mode substitution does not take place. Finnair's rail services can be viewed as an access service to Zürich airport, which

³⁹ To destinations to which local demand alone is not sufficient to justify services.

increase the airport catchment area, and is likely to benefit the airline, the airport, and the TOC. In addition, it is beneficial to the airline's passengers, and society (in the form of reduced environmental pollution if the new service results in diversion of trips from the car to the train). Because under this form of integration, mode substitution does not take place, rail services cannot relieve aircraft congestion, and cannot lead to reduced environmental impact from the ATI operation. Moreover, under such integration, the rail service does not necessarily need to be a HST service.

This research is concerned with airline and railway integration that leads to substitution of aircraft services by HST services. Lufthansa (LH) was probably the first airline to experiment with such integration. Between 1982 and 1993, LH operated train services, called the Lufthansa Airport Express, between Frankfurt airport and the city of Düsseldorf. These services enabled LH to meet the growing demand for air services between the cities without having to expand flight frequency on this short-haul feeder route (EC, 1996). However, the service was not considered a success and was stopped when the TOC, Deutsche Bahn (DB), decided to increase the charter rates of the trains. In addition, the Lufthansa Airport Express service was not a HST service. The route's 190 km were covered in two and a half hours, an average speed of 76 kph, which probably meant that the train was not an attractive substitute for the plane.

However, since March 2001 LH again offers rail services, from Frankfurt airport to Stuttgart city centre, as an integral part of its route network (Sharp, 2003). The integration of LH services with the DB services is complete, and is considered to be the benchmark for aircraft and HST substitution under airline and railway integration. In addition to all the features of the Finnair rail service described above, it offers LH passengers a dedicated car on the train, which is reserved solely for LH passengers. The onboard service is comparable to the service typically found onboard European short-haul flights and is provided by DB staff (IATA, 2003) thus, LH's aircraft environment is almost replicated by the train service.

Although the integration between the aircraft and train service is complete, the LH 'AIRail' service, as it is branded (LH, 2002), is different from the airline and railway integration envisaged in this research by the fact that LH offers a limited capacity of 46 seats (less than the smallest aircraft in LH's fleet) on each of the seven daily return train services (Weinert, 2002). More important, the company still offers flights on the route. However, from March

2003, following the opening of the Frankfurt-Cologne HST line, LH will extend its rail services for this route and will withdraw parallel flights (Sharp, 2003)⁴⁰.

There are increasing numbers of companies pursuing integration of rail services into their (aircraft) route network. Such integration follows both the Finnair and the LH forms of integration. AF signed an agreement with the French National Railways (SNCF), and later launched the 'TGV Air' services where SNCF serves CDG airport from a dozen relatively close destinations as part of the AF route network (Zembri, 2003). This agreement includes services from CDG to Lyon, where the TGV replaces some, but not all, AF flights. On this route, CDG-Lyon, SNCF also code-shares its TGV service with United Airlines (Railway Age, 2001). On the CDG-Brussels route, AF has a code-share agreement with the TOC Thalys where the HST service replaces all AF flights on the route. In addition, Thalys has a code-share agreement with KLM on journeys from Schiphol to Antwerp. The US based airline Continental and Scandinavian airlines SAS both use agreements with TOCs to enhance their network on both sides of their trans-Atlantic routes. Continental started a code-share with SNCF in February 2003 that allows continental passengers to travel by TGV to 13 destinations in France, and in the US Continental has the same agreement with the TOC Amtrak for destinations from Newark airport. As a result of the agreement with Amtrak, Continental withdrew flights to Philadelphia and added to its network destinations like Wilmington, Stamford, and New Haven which continental has never served before (Sharp, 2003). SAS is also planning an agreement with Amtrak for the latter to serve SAS passengers arriving at Newark airport on the Washington-New York-Boston rail corridor⁴¹. On the European end of the route, SAS is already selling through tickets to destinations in Scandinavia beyond Copenhagen, and Stockholm, served by the Swedish and Danish state railways, replacing flights with rail trips (Railway Age, 2001).

For airline and railway integration to be worthwhile to the operators and attractive to passengers, a number of conditions must be satisfied. The initial and basic requirements are for a long-distance train station at the hub airport and a HST service to be available (Weinert, 2002). On top of that, according to Pavaux (1994)⁴², the following conditions must be satisfied:

Excellent interconnections between the rail and air networks i.e... fully coordinated rail and air schedules; ...[possibility] to check-in luggage from the origin to the final destination; [and] there must be commercial cooperation

⁴⁰ To date, LH still operates flights on the route.

⁴¹ Amtrak is operating the Acela Express, a tilting train service, on this corridor.

⁴² Pavaux (1994) refers to complementarity between HST and air transport at times when an example of such a service was the Lufthansa Airport Express (see above). Nevertheless, the same conditions apply to airline and railway integration.

between the railway companies and the airlines to offer, on the same computer reservation systems, travel options combining the two modes with special fares

(Pavaux, 1994: 7).

Commercial cooperation between the operators should allow the passenger to make one reservation and receive one ticket that covers the whole journey (Buchanan and Partners, 1995). These requirements are fully met in the Finnair and LH examples of airline and railway integration.

The rest of this research focuses on airline and railway integration in which the rail service substitutes an existing aircraft service, the LH model described above. Apart from the operators and the airline passengers, another major stakeholder in any integration between airline and railway is the airport operator. This stakeholder is discussed next.

2.3.4 The interface point between the train and the plane – the airport

The airport has two roles to play in airline and railway integration. First, it supplies part of the infrastructure required, and second, it is an important stakeholder in such integration. This section, and the research in general, focus on the former role.

As a stakeholder, the airport has a lot to gain from airline and railway integration. Airport operators are constrained and affected by capacity shortage and environmental constraints as much as the airlines. Airports might even be more affected than airlines since airlines sometime have the possibility to operate from a different airport. As a result, the option to increase airport passenger throughput without increasing runway and ATC capacity, and with almost no additional environmental impact, by shifting traffic to HST, is potentially beneficial to airports as much as to airlines. The fact that operators of major airports see an increasing part of their revenues coming from non-aeronautical sources (i.e. not from aircraft landing and parking charges), but mainly from commercial activities within the terminal (Graham, 2001), means that the crucial factor determining revenues is the number of people using the airport, not the number of aircraft.

Following the development of the H&S system, the airport became, in addition to being a point of origin or destination, an intermediate point where passengers transfer between two connecting flights. At major airports, sometimes more than 50% of the passengers (amounting to 51 million passengers at Chicago airport) are transfer passengers. These airports specialise in making the transfer of passengers and their luggage between flights smooth and fast. The luggage is moved between the two flights without the intervention of the passenger, making it easier and convenient for the passenger to change between aircraft.

In addition, airlines and airports try to reduce the inconvenience to passengers from having to transfer between flights⁴³ by trying to limit the distance the passenger has to walk between flights, by providing appropriate guidance and signage, and by coordinating the flight schedule to reduce waiting time⁴⁴. “For passengers to consider changing to the train for the second stage of their journeys a similar level of service needs to be offered” (Buchanan and Partners, 1995: 6-22).

The significance of the interchange characteristics to passengers’ views on airline and railway integration was evident in an IATA survey which aimed to receive passenger feedback on the scope for ‘air/rail intermodality’. The survey found that passengers’ main reason for not using a HST before/after flying (after the reason of no rail services (51%)), was connection issues (39%), followed by schedule (19%). The most common answer to “what should be improved in air/rail intermodality?” was: “easier connections” (41%), followed by “scheduling” (just over 10%). Finally, when respondents were asked how they would invest €10 in air/rail intermodality? they allocated most of the money (€2.4) to connecting times/access, followed by price (€2.1), and punctuality/reliability (€1.6). IATA concludes that “connections issues are perceived as one of the major barriers [to air/rail intermodality]” (IATA, 2003: 33).

The inconvenience to the passenger from having to change between the plane and the train depends to a great extent on the configuration and location of the rail station in relation to the terminal building. Two broad configurations can be identified: one is to build the interchange under the existing air terminal complex, and the other is to build it adjacent to the air terminal and at the same level (Buchanan and Partners, 1995). Amsterdam, Stansted, Zürich and Tokyo Narita airports follow the first configuration, while Frankfurt, CDG, Gatwick and Manchester airports are examples of the second configuration. Buchanan and Partners (1995) note that:

Many would consider the best location for a rail/air interchange is under the air terminal complex...The location of the rail station under the terminal has the additional benefit of making the airport and rail station appear well integrated, which is an important perception for air passengers when making a mode choice
(ibid, 6-20).

Whether the rail station is located under or adjacent to the terminal, the level of inconvenience in the transfer between the modes will be determined by the distance and change of level between the (aircraft) gate and the (train) platform and the means provided to

⁴³ See section 4.2.

⁴⁴ And at the same time allow sufficient time for passengers and their luggage to arrive at the connecting flight.

the passenger to overcome those, e.g. travelators, elevators, people movers, etc. (IARO et al, 1998). At Oslo's Gardermoen airport, for example, "the station is closer to the terminal than the car parks - an excellent incentive to use rail" (ibid, 93).

As noted above, the attraction of an air-rail service to passengers depends very much on whether the rail station is connected to the airport luggage distribution system. Such a connection is currently in operation only at Frankfurt airport.

In conclusion, although the 'airport' is likely to benefit (and hence invest) in airline and railway integration, it will not be part of the empirical analysis in this research⁴⁵. However, it has a major role to play as the provider of the infrastructure which allows integration between the modes to take place. The interchange is a crucial element in the overall passenger experience of an intermodal journey, and thus a crucial element in determining the success of airline and railway integration, and of aircraft and HST substitution.

⁴⁵ The benefits to airports from the provision of HST services are discussed in section 5.1.2.

2.4 Airline and railway integration - a new approach to intermodality

At the beginning of the 20th century, in the early days of commercial aviation, it seemed aircraft services would not be a threat to the established railway services. Most of the journeys in that period were land journeys, and rail journeys were faster, more comfortable (often with sleeper accommodation), running directly between city-centres, and much safer than the aircraft journeys (Staniland, 2003). The scope for commercial aircraft services, it seemed, was in providing services over large water bodies, competing with the sea modes. From this beginning the ATI developed, through exploitation of technological developments, to become the main mode of transport for long distance travel, also on routes where traditionally the railways dominated. The growth and success of the ATI in providing transport services led, towards the end of the century, to a situation in which the industry could not meet the demand for its services. In addition, growing concern with the environmental impact imposed on society by the operation of the ATI threatens to limit its operation. Amidst the constraints faced by the ATI, which already manifest themselves in the form of delays to air services, and high air and noise pollution around airports, the railways could 'take' back some of the traffic they lost to the airlines. This became possible due to the development of the HST.

Traditionally, the modes compete with each other on routes where they provide comparable travel times. However, with an increase in congestion and environmental concern, the ATI is starting to see an opportunity, rather than a threat, in the railways, paving the way for cooperation. Predominantly, such cooperation takes the form of using the railways as an access mode to airports. Although this cooperation between the industries is mainly between the 'railways' and the airports, airlines increasingly take part in cooperating with the railways in this market by encouraging their passengers to use the rail to access the airport (through free or discounted tickets for the rail journey, and by check-in facilities at rail stations).

Another form of cooperation is where the rail service substitutes the aircraft service. Carrying passengers is the airlines' core business, and therefore airlines are not likely to 'surrender' services to the railways. Therefore, for such cooperation to take place, substitution of the modes (aircraft by HST) without substitution of the service provider (from the passenger aspect) must take place. This leads to a situation where services provided by the airlines using aircraft are still provided by the airline, but by using HSTs. Airlines

probably have no interest, at least in the near future, in operating rail services and adding trains to their aircraft fleet⁴⁶. Hence, cooperation as described above can take place if the TOC operated the rail service provided by the airlines. For such cooperation to work the level of cooperation between the airline and the TOC must lead to a full integration of the aircraft and the rail service. This type of cooperation is the focus of this research and it is an innovative approach to investigating aircraft and HST substitution.

In order to make clear the differences, in this research, between airline and railway competition, cooperation, and integration, the following definitions are given:

Competition between the airlines and the railways takes place on routes where both offer (separate) services.

Cooperation between the airlines and the railways takes place on routes where the rail and the aircraft journeys complement each other and one mode does not substitute the other⁴⁷.

Integration between the airlines and the railways takes place on routes where the rail and the aircraft journeys complement each other but the train substitutes the aircraft on the railway segment of the journey.

Competition, cooperation, and integration can all take place within the same railway service. For example, on the Stuttgart-Frankfurt HST service, passengers travelling between the cities could have chosen to use the aircraft and therefore they represent airline and railway competition, in this research. Non-Lufthansa passengers flying to anywhere in the world from Stuttgart through Frankfurt airport and using the HST to access the airport represent airline and railway cooperation. And, Lufthansa passengers, on the same HST service between Stuttgart and Frankfurt, flying to anywhere in the world from Stuttgart through Frankfurt airport using the Lufthansa 'AIRail' service represent airline and railway integration.

In the case of cooperation and substitution, the railway services are provided from/to the airport. Therefore, the first condition for cooperation and integration to take place is a rail station at the airport. For integration to take place, another condition is that the airport station accommodates HST services. The recognition of the potential in cooperation and integration (probably more the first) is evident in the increasing number of airport rail stations built, being built, or planned. "At a total of 32 airports in 29 cities in over 15 European countries, there are currently or planned rail stations served by long distance rail link" (EC, 1998: 72).

⁴⁶ "It also appears that airlines themselves are not the best providers of rail services" (Buchanan and Partners, 1995: 10-4).

⁴⁷ Note that Finnair's service to Bern falls under this definition, although described earlier under integration.

As noted earlier, aircraft and HST substitution are increasingly recognised as one way to confront the problems faced by the ATI. Yet, if such substitution leads to competition, it might even exacerbate the problems faced by the ATI (due to airlines' reaction to the competition). For this reason, it is assumed that by avoiding direct competition between the airlines and the railways following mode substitution, the ATI can enjoy the benefits provided by substitution. If airlines will not benefit from mode substitution it will not take place, thus preventing benefits to passengers and the environment from materialising. Based on this assumption, this research adopts airline and railway integration as the preferred model for aircraft and HST substitution.

In addition to the definition of integration given above, integration means, and requires, seamless transfer between the plane and train, and that the 'airline' HST service is integrated with the TOC city-centre to city-centre service.

Integration of the aircraft and the HST service means that the transfer between them is as seamless as possible, and is similar to the transfer between two flights operated by the same airline. Especially important is that the transfer time is kept to the minimum, and the luggage is transferred between the services without the involvement of the passengers. These features represent the airports' role, other than providing the HST station, in airline and railway integration. They must be equipped to offer Minimum Connecting Time (MCT) between the aircraft and train equal to the MCT they guarantee to airlines for transferring passengers and luggage between two flights. The operators on their part need to insure that ticketing and seat allocation will be provided by each operator for the entire journey (i.e. one ticket for the aircraft and HST journey), and that other services (such as onboard services and customer service) will be of similar standard. Finally, to provide relatively 'stress-free' transfers, the airline must take responsibility if passengers miss a connecting HST service in the same manner it would have if passengers missed a connecting flight.

IATA (2003) examined the potential for integration, in the way defined here, by considering the demand for air services to see if this could justify using the HST as a substitute for the aircraft (on distances appropriate for HST to substitute the aircraft). Yet, when integration also means that the TOC continues to serve demand on the origin-destination market, in addition to the airlines' passengers, the demand which is shifted from the aircraft does not need to be high to justify mode substitution. In other words, even if demand from the airport is relatively low, HST services can be justified if demand from the city centre is high enough. Thus, airline and railway integration between Lufthansa and Deutsche Bahn (DB) on the Frankfurt airport-Stuttgart route is justified even though Lufthansa requires a capacity of only 48 seats on the train, because DB continues to serve the Frankfurt to Stuttgart route

where demand is high enough to support HST services. This approach is supported by the conclusion that “it does not seem possible to operate a viable long distance rail service on the basis of airline passengers alone” (Buchanan and Partners, 1995: 10-4), and it might mean that the scope for mode substitution, and its potential benefits, are larger than usually anticipated. The scope for substitution is often considered to be 10% of European internal passengers (Sharp, 2002), 10% of European scheduled airline capacity (Caves and Gosling, 1999), or 10% of all air passengers at the airport concerned (Buchanan and Partners, 1995)⁴⁸.

The definition of airline and railway integration given above sets the context for this research and the context for the evaluation of benefits from airline and railway integration which is at the centre of the research. Before the empirical analysis is presented (section 4), the methodology used for this analysis is presented in section 3.

⁴⁸ This is estimated for Heathrow in section 4.4.3.

3. Theoretical and methodological framework

The main aim of this research was to empirically test the concept of airline and railway integration. This section describes in detail the concept envisaged in this research and the methodological framework in which it was evaluated. It also provides the theoretical background on evaluation methods and practices.

The first part (section 3.1) describes the concept of airline and railway integration and the general framework in which it was tested, including the choice of case study route. The second part (section 3.2) looks in more detail at the empirical evaluation of benefits from integration and the use of evaluation methods. The last two parts further focus on specific aspects of the empirical analysis, the evaluation of travel time savings in monetary units (section 3.3) and the evaluation, in different units, of environmental benefits (section 3.4).

3.1 Airline and railway integration - research methodology

The approach to the empirical analysis which is at the heart of the research is outlined in this section. First, the ideological approach to evaluating airline and railway integration is discussed, followed by a discussion on the methodology adopted to carry out an empirical evaluation of airline and railway integration. This section also presents the case study route and discusses the data aspect of the empirical analysis.

3.1.1 Research methodology - the ideological approach

Aircraft and HST substitution is not a new idea. As stated, Bromhead in 1973 has already discussed the possible use of trains to substitute air services in order to meet the forecast for growth in demand for air travel in the South East of England (Bromhead, 1973). Since then, and as a result of the development of the HST, plane and train substitution has been discussed, debated, and researched constantly. However, in almost all the cases mode substitution that leads to competition between the modes and the operators was considered (e.g. EC, 1998; AEF, 2000; CfIT, 2001a).

Airlines can respond to such competition in two ways: withdraw services from the route, or 'fight back', the latter seems more probable (see section 2.3.1). The main reason seems to be the desire to maintain the route as part of the airlines' network and as a feeder to other routes. Consequently, aircraft and HST substitution which lead to competition between operators could lead to overall disbenefits from mode substitution, especially if the airlines respond to competition with an increase in flight frequency leading to increase congestion and environmental impact. A different approach, therefore, is tested in this research where the operators cooperate and integrate their services rather than compete with each other. This approach, it is believed, would benefit both operators, a prerequisite for cooperation, the users and society in general, and it is therefore desirable from almost every aspect.

The main interest of airlines in mode substitution is probably the ability to keep traffic feeding into the (more profitable) long haul routes while not consuming valuable slots at congested airports for the use of short haul (feeder) routes by small aircraft. In this respect, airline and railway integration is most suitable for airlines operating H&S strategy. This

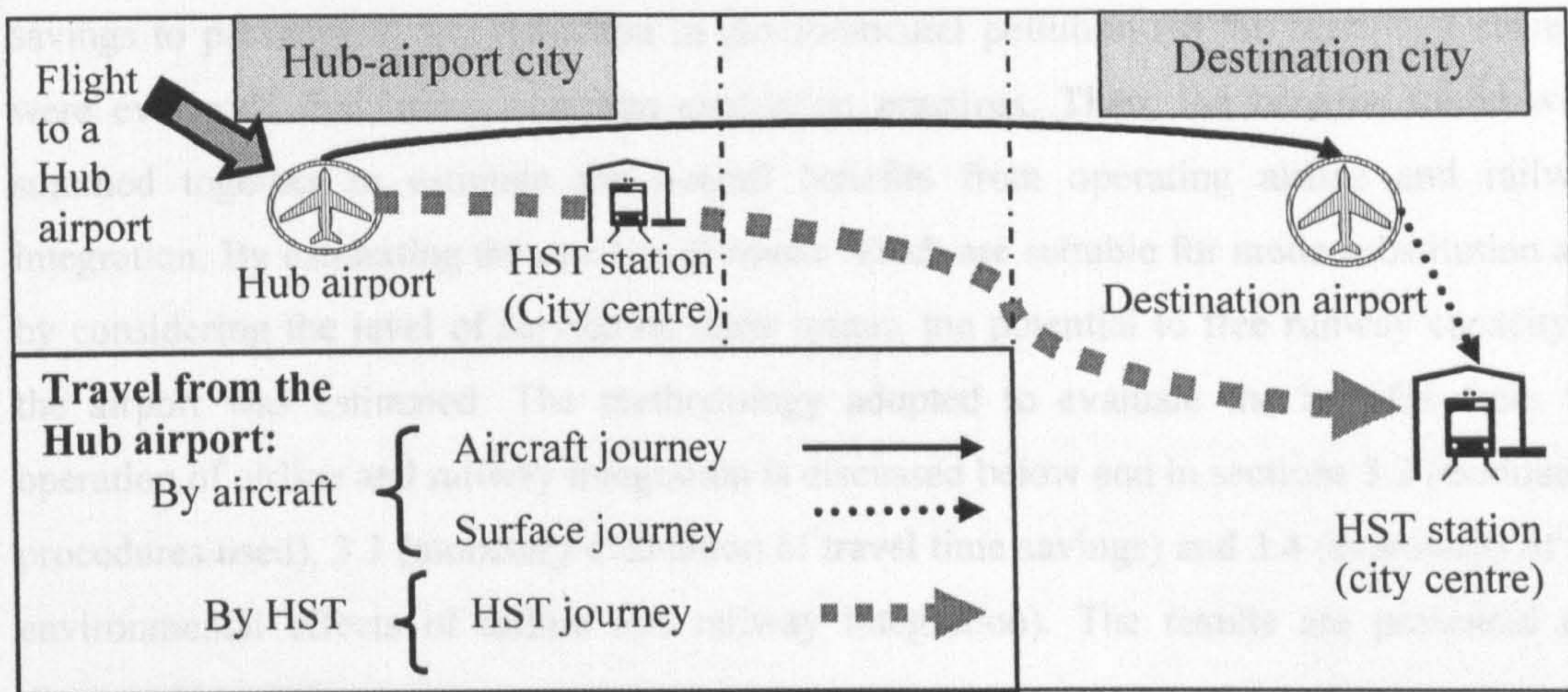
means that the transfer traffic market is the main concern of this research⁴⁹. In this market, passengers' journeys consist of two legs (sectors): a flight from an origin airport to a hub airport, followed by a flight from the hub airport to a destination airport. One of these flights is often a short haul flight that can be served by HST. The idea of airline and railway integration is that the airline continues to offer such a service but the short haul leg of the journey is served by a HST service which is operated by a TOC. Furthermore, it is assumed that only if the operators integrate their services can mode substitution be attractive to airline passengers. Especially important, in this context, is a relatively fast and seamless transfer between the modes at the airport.

Defining the relationship between the airline and the TOC (i.e. cooperation to the extent of service integration) and identifying the market that will be the focus of the research (the transfer traffic market) sets the broad framework of the research. This framework, the basis for the empirical research part, is outlined in Figure 6. Passengers flying from their origin to their destination through a hub airport currently transfer at the hub airport between two aircraft services. Upon arrival at the destination airport, passengers complete their journey by using a surface mode to arrive at the city-centre, assumed to be their final destination. This is the aircraft (or air) journey option, in which mode substitution does not take place. Alternatively, passengers transfer at the hub airport to a HST service which takes them directly to the destination city city-centre. This is the HST journey option which represents aircraft and HST substitution under airline and railway integration. The HST service from the airport also serves the (hub-airport city) city-centre to (destination city) city-centre market. It is assumed that this service already existed before airline and railway integration began.

It must be acknowledged that passengers' final destination is usually dispersed over a large area and that the majority of passengers would probably not travel to the city centre. However, it is reasonable to consider the city centre as the geographical mean of passengers' final destination. Furthermore, the city centre is, in most cases, the location that attracts most of the airport passengers. For example, in 2001 35% of the passengers accessing Heathrow came from central London, 18.1% from outer London and 30.8% from South East England (BAA, 2002). The importance of the city centre as the final destination of an airport's passengers can explain why most of the dedicated rail services to airports are services to/from city centres. Accordingly, it is reasonable to consider the city centre as the passenger final destination.

⁴⁹ As noted earlier, at the main European hub airports this market is a big part of the overall traffic (see section 2.1).

Figure 6: Aircraft and HST options of travel between the hub airport and the destination city



Within the framework defined above, the research aim is to **empirically** evaluate the benefits from aircraft and HST substitution that takes place under airline and railway integration. Such evaluation must consider the different stakeholder groups affected by airline and railway integration and the different effects. These effects are diverse and some are indirectly the result of airline and railway integration, for example, and especially, if due to airline and railway integration the airport is provided with a HST link that improves the means to access it and increases its catchment area. In this case, the cost of constructing the HST link to the airport must be considered as well. In addition, some of the effects are likely to be positive to one group of stakeholders and negative to another⁵⁰.

In order to overcome some of the obstacles described above and to disentangle the different effects, a distinction between direct and indirect effects was necessary. The focus of the empirical evaluation was on the former to allow in-depth analysis leading to identification of potential benefits from mode substitution (under airline and railway integration) and robust measurement of these benefits. In regard to the benefits from mode substitution, the literature does not provide enough evidence why this is desirable other than, in most cases, stating that this is the case, especially with regard to the environmental effects.

The direct effects were considered to be the direct effects from the **operation** of airline and railway integration. Specifically, potential benefits for the following stakeholder groups were evaluated: the operators (airlines which adopt mode substitution⁵¹), the users (passengers that

⁵⁰ For example, if airlines used the freed slots to add (long haul) services the overall negative environmental impact would rise.

⁵¹ As noted in the introduction, because it is mainly a decision for the airline to make, whether to substitute the aircraft with the HST, the research is more concerned with evaluating the benefits to airlines. Potential benefits to the railways and airports are discussed in section 5.

were shifted from the aircraft to the HST), and society (effected by the environmental implications of mode substitution). Operating cost (OC) savings to airlines, travel time savings to passengers, and reduction in environmental pollution (to the benefit of society) were evaluated first, using common evaluation practices. Then, the benefits found were summed together to estimate the overall benefits from operating airline and railway integration. By estimating the number of routes which are suitable for mode substitution and by considering the level of service on these routes, the potential to free runway capacity at the airport was estimated. The methodology adopted to evaluate the benefits from the operation of airline and railway integration is discussed below and in sections 3.2 (evaluation procedures used), 3.3 (monetary evaluation of travel time savings) and 3.4 (evaluation of the environmental effects of airline and railway integration). The results are presented and discussed in section 4.

Based on the evaluation of direct benefits, airline and railway integration was examined in a wider perspective (section 5). In this part of the research, indirect benefits were considered. A discussion, rather than a full empirical evaluation, is the approach taken in order to contain the subject within the scope of the research. Other than the indirect benefits, the different issues related to how integration would work in practice, the general implications of integration for the ATI, and its policy aspects were considered. In this part, an increase in the airport capacity from the connection to the HST network was weighed against an increase from the provision of new runway capacity. The cost of the two options was also considered.

Accordingly, and in general, the benefits from the operation of airline and railway integration (the direct benefits) can be viewed in two different contexts: the benefits from replacing an existing aircraft service with an existing HST service (i.e. simply shifting the passengers between the modes), and the benefits from providing a future service by HST and not aircraft. The second context implies that the infrastructure to provide HST services at an airport is a substitute to new runway capacity, and this approach dominates the discussion in section 5.

3.1.2 Research methodology - the empirical study: operating airline and railway integration

The research focus, and one of its main challenges, was the empirical evaluation of the direct benefits from airline and railway integration. The general framework for the empirical analysis, as outlined above, includes evaluating benefits of reduced operating costs to airlines, reduced travel time to passengers, and reduced environmental impact to the benefit of society.

Comparison between different modes raises different methodological obstacles that must be overcome in order to yield a sound analysis and robust results. To some extent, a comparison between a train and a plane is like ‘adding apples and oranges’, in economists’ jargon, which means that a ‘like with like’ comparison is hard to achieve. Accordingly, one of the methodological challenges in this research was to find, for each aspect evaluated, an appropriate way to reach a ‘like with like’ comparison between different modes. The main obstacle is the different capacities of the modes.

To overcome the capacity differences, a common capacity unit for both modes must be used. The options, in the context of passenger transport, are to use seat or passenger units. Many empirical studies choose the passenger as the unit of analysis mainly because the transport of passengers is the goal of transport services. However, in this research seat units are preferred. The main reason is that mode substitution is between one aircraft journey and one HST journey, or one aircraft-seat journey and one HST-seat journey, the passengers remain the same passengers whatever mode of transport is used. Furthermore, the research accepts the IARO’s chairman view that “passengers do not care how they get from A to B as long as it is convenient, comfortable and fares are acceptable – and, ideally, they get their air miles” (Sharp, 2002: 5).

Other reasons for preferring seat units over passenger units are as follow. The research in general is more concerned with the supply of, rather than the demand for, services. Accordingly, it is assumed that airlines will shift the supply of seats from the aircraft to the HST, maintaining the same seat capacity on the route, because of its effect on the OCs and not on the revenues. Whether these seats are actually filled with passengers or not is outside the concern of the research since the airlines have already considered, and decided, to supply them on board the aircraft. Another argument in support of the use of seat units is that the impact from a train journey and an aircraft flight is directly related to the capacity provided. For example, the cost of operating a HST or an aircraft service is almost fixed in relation to the number of seats actually filled with passengers (the load factor (LF)). In the same manner the environmental impact of a flight or a HST journey is (almost) not related to the actual number of passengers using the service⁵². Travel time savings to passengers are of course measured in passenger units, but in order to allow summation of the benefits across all categories they were also converted to seat units (by assuming a certain LF for each mode).

⁵² For a given flight, the extra weight of additional passengers, and their luggage, might influence aircraft fuel consumption, and therefore the OCs and environmental impact. However, this is considered to be marginal.

There are, however, some limitations in choosing the seat unit. First, the LF of HST services is on average usually lower than the LF of aircraft services, which means that aircraft are more efficient in using their capacity and therefore impose relatively less impact per passenger transported. Hence, given the HST lower LF, choosing the seat rather than the passenger unit would give some advantage to the HST. Second, the overall impact of a journey is overlooked, but this can be easily overcome by multiplying the effect per seat in the number of seats shifted from the aircraft to the HST. Third, it overlooks the effect of the overall changes in the number of aircraft and HST services on the route, but this also can be easily evaluated by multiplying the effect per seat by the change in the number of (HST or aircraft) services.

Another obstacle to reaching 'like with like' comparison between aircraft and HST journeys is the different distances each mode covers on the same route. Different land modes would usually cover similar distances between origin and destination, but this is different when comparing land and air modes since the latter is not constrained by terrain and natural barriers like mountains and large water bodies, and hence in most cases covers shorter distances. Furthermore, in the case of HST the route often deviates from the direct route to serve additional cities⁵³. The differences between the aircraft and the HST route distance on routes suitable for mode substitution are shown in Table 4⁵⁴. For the aircraft, it was assumed that the route distance is 10% longer than the great circle distance (the shortest possible distance) to account for ATC and airport approach and departure restrictions. The common practice to ensure that the comparison is between modes and not route characteristics is to adopt the same unit of distance, usually one km. However, in the case of aircraft and HST substitution the differences in the route distance become a characteristic of the mode itself since they are fixed and given for each route. As a result, the unit of distance adopted in this research is the route, allowing the different distance each mode covers to affect the results. Simple manipulation would also allow the results to be presented in km units to permit transfer of the findings to other routes.

⁵³ The principles of route location are explained by Black (2003): if a transport surface is uniform (the general case for aircraft) the optimal route between two termini is a straight line. If a transport surface has two distinct cost surfaces (e.g. flat and mountainous terrain, the latter results in higher construction costs of HST line), the optimal route between an end point in one zone and an end point in another zone will bend (thus, the route costs and not distance are minimized). And, whether an intermediate place (e.g. a city) is connected to a transport line is a function of its revenue-generating ability and the cost of deviating from the least cost route.

⁵⁴ In relation to mode substitution, it is interesting to note with relation to the European routes in Table 4 that analysis of delays to European air services in 2002 found that "the busiest city pair [in terms of ATMs], as in previous years, was Madrid-Barcelona, with over twenty two thousand flights in each direction...Other busy pairs included Rome-Milan/Linate, Barcelona-Palma, and London/Heathrow-Paris/Charles de Gaulle, all with over ten thousand flights in each direction" (CODA, 2003: 9).

Table 4: Aircraft and HST route distance for different routes

	Route distance (km)			Ratio HST/Aircraft route distance
	Great circle ¹	Aircraft ²	HST ³	
Heathrow - Paris	348	383	525 ⁴	1.37
London - Paris	348	383	495	1.30
Tokyo - Osaka	401	441	553 ⁵	1.25
Paris - Amsterdam	398	438	540	1.23
Madrid - Barcelona	483	531	630	1.19
Beijing - Shanghai	1,077	1185	1,300	1.10
Naples – Milan (LIN)	650	715	739	1.03
Rome – Milan (LIN)	485	534	519	0.97

¹ Great circle distance (source: Landings.com, 2003).

² Great circle distance plus 10%.

³ Source: UIC (2003).

⁴ Assumed in the research.

⁵ Source: Central Japan Railway Company (2003).

A methodological problem that is common to all comparisons between projects, policies, change in operation, etc. is how to compare between different impacts, for example time savings and OC savings. The solution usually adopted is conversion of all the impacts to monetary units. This also allows comparison between the benefits and the costs of a project/policy/change in operation. Such a methodology, commonly termed Cost Benefit Analysis (CBA), is adopted in this research in order to sum different benefits of operating airline and railway integration.

Despite the advantages of using CBA, it has its limitations. These limitations are mainly associated with the process of converting different effects to monetary value. This is mainly evident when evaluating the cost of environmental impact. As a result, the CBA might lead to questionable results that are not robust enough as a basis for conclusions. An alternative approach is to present each effect measured in the most appropriate units and to avoid summing up the effects. This methodology, termed Multi Criteria Analysis (MCA), is used in this research to complement the CBA. Background information on the CBA and the MCA, and the way they are used in this research, is given in section 3.2.

To empirically evaluate airline and railway integration, one case study route was selected, the Heathrow airport to Paris route. The reasons for choosing it and its main characteristics are discussed next.

3.1.2.1 The case study route – London Heathrow to Paris

London and Paris as a city pair follow the general characteristics, described in section 2.2, for a successful HST service. These include the distance between the cities (about 350 km

direct distance); the cities' population (London 7 million and Paris 11 million (CfIT, 2001b)); and the high demand for travel between the cities (evident in the number of air and HST services directly connecting the cities: 51 flights⁵⁵ (Innovata, 2003) and 14 HST services (Eurostar, 2003b) on a week day during summer 2003).

Until the opening of the 50 km Channel Tunnel in 1994, rail connection between the cities was not possible. After the opening of the Channel Tunnel, train services between the cities began by Eurostar, a newly established TOC. In 2007, when the construction of the Channel Tunnel Rail Link (CTRL) which connects London with the Channel Tunnel will be completed, the HST line London-Paris will also be completed. The London terminus of the HST route will be at St. Pancras.

Table 5: HST and aircraft market share on the London-Paris route (percentage)

	November 2003	November 2002
Eurostar	66.0	58.1
BA	13.2	15.2
AF	11.5	13.5
EasyJet	5.0	5.3
bmi	4.3	5.1
Buzz	0.0 ¹	2.6
Other	0.1	0.3
Total	100	100

¹ Low cost airline Buzz was bought by Ryanair, another low cost airline, in 2003.
Source: Eurostar (2004a).

The opening of the Channel Tunnel and the beginning of HST services between the cities with three hours city centre to city centre travel time⁵⁶ made the train a viable alternative to the aircraft and resulted in competition between the modes. Although Eurostar was able to gain the largest market share on the route, even more so after the opening of section 1 of the CTRL, a significant part of the market is still served by airlines (=aircraft). In November 2002, the market was divided 58% and 42% between HST and aircraft services respectively, changing, after section 1 of the CTRL opened, to 66% and 34% in November 2003 (Table 5). Most of the aircraft services are from Heathrow (all bmi services, and most BA and AF

⁵⁵ One way services, divided between the London airports as follows: Heathrow 31 daily flights, Gatwick 6, Luton 5, and City 9 (Innovata, 2003).

⁵⁶ Reduced to 2h40m in September 2003 when the first section of the CTRL opened. It is expected to be further reduced, to 2h15m, once section two of the CTRL opens in 2007 (CTRL, 2004).

services) and it can be assumed that a significant part of those serve the transfer traffic market⁵⁷.

At the time when competition between the modes on the London-Paris route takes place, the skies over Europe are increasingly congested, especially over South East England and at the London airports, leading to a high level of delays (see Appendix A). Considering the lack of capacity, especially at Heathrow, the 21,752 flights which operated between Heathrow and CDG during 2001 (CODA, 2002) can be seen as a waste of valuable runway and ATC capacity. These flights represented 4.2% and 4.7% of the total ATM capacity in 2001 of CDG and Heathrow respectively⁵⁸. The recommendation to build a new terminal at Heathrow (Terminal 5) with restriction on the airport yearly ATM capacity to only 480,000 (Vandermeer, 2001), almost the present capacity used, and the proposal to build a third runway at Heathrow for the use of short-haul flights only (DfT, 2003a), further emphasizes the 'waste' of using the limited capacity for services that could be served using HST. One of the main reasons to build both the new terminal and (in the future) the new runway is to prevent Heathrow from losing the competition with its main rivals: CDG, Schiphol and Frankfurt airports. This competition is mainly on the position as a hub airport, i.e. the competition for transfer passengers.

The Paris-London route characteristics, the availability of HST services on the route, and the capacity constraints at Heathrow (together with the pressure to increase this capacity), makes the Heathrow-Paris route a good case study for this research. Specifically, the debate in the UK regarding Heathrow's third runway (prior to the publication of the aviation White Paper (DfT, 2003b)), a debate in which the idea of a HST link to Heathrow as a means to increase its capacity and preserve its role as a hub airport is virtually missing, makes the selection of the case study particularly important and timely. Finally, from all the routes currently served from Heathrow that are suitable for airline and railway integration, the route to Paris 'consumes' most of the runway capacity (see section 4.4.3).

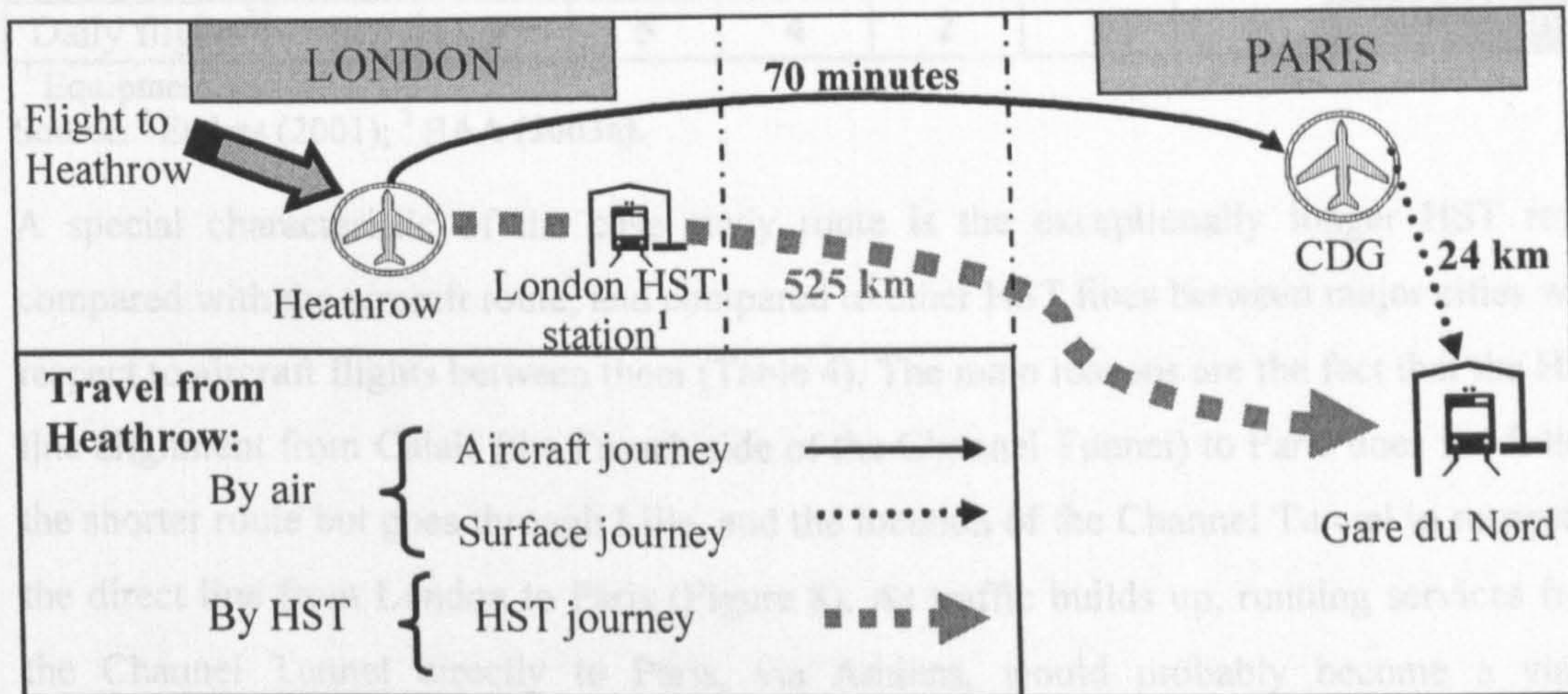
Using the research framework depicted in Figure 6, Figure 7 outlines the case study route. Currently, passengers flying to Paris via Heathrow transfer at Heathrow to a flight which takes them to CDG where they transfer to a surface mode to complete the journey to Paris city centre. This is the aircraft journey. Under airline and railway integration, the passengers arrive at Heathrow by a flight and transfer to the HST which takes them directly to Paris Gare-du-Nord HST station, assumed to be at the city centre. The HST service from

⁵⁷ However, for AF transfer passengers, CDG is the hub airport and Heathrow is the destination/origin airport.

⁵⁸ 523,400 ATMs in CDG and 463,568 ATMs in Heathrow during 2001 (ACI, 2003).

Heathrow also serves the London-Paris market by stopping at the London HST station, assumed to be 30 km from Heathrow.

Figure 7: Aircraft and HST options of travel between Heathrow and Paris



¹ The London HST station can be either at St. Pancras, Stratford or Ebbsfleet, all are planned stations on the CTRL. For the research, it is assumed that the London HST station is located 30 km from Heathrow (based on 15 miles Heathrow-city centre (TCRP, 2000)).

The HSTs currently operating on the route are all Class 373 Tricourant trains. The 394 meter long trains comprise 18 passenger carriages and two power cars, and have a capacity of 766 seats which is fixed (Eurostar, 2003a; UIC, 2003). The aircraft models used on the Heathrow CDG route vary quite often, and hence the capacity on each service is not fixed.

The Boeing 737 (henceforth B737) is the most common narrow body aircraft (aircraft typically used on short haul flights) in the world. In 2000, 2,377 aircraft of this type were in service, more than 30% of the world's total narrow body aircraft, and an additional 393 were on order (IATA, 2001). Therefore, the B737 was initially considered as the benchmark aircraft for use in the analysis. However, during the summer of 2003, none of the airlines operating flights between Heathrow and CDG used this model (Table 6). The Airbus A320 (henceforth A320) was almost the most frequently used model on the route (used once less than the Airbus A319) and its capacity is closest, from the aircraft operating on the route, to the average seat capacity across the services operated on the route (Table 6). In 2000, the A320 was the fourth most common aircraft in use with 687 aircraft in service, over 9% of the world's narrow body fleet, and with 266 orders in 2000 (ibid). Therefore, the A320 was selected as the benchmark model for use in the analysis. The selection of aircraft model is important not only to determine the seat capacity but also to determine other important parameters in the evaluation such as OCs and CO₂ emission, for which model-specific data is available.

Table 6: Models of aircraft used between Heathrow and CDG during summer 2003

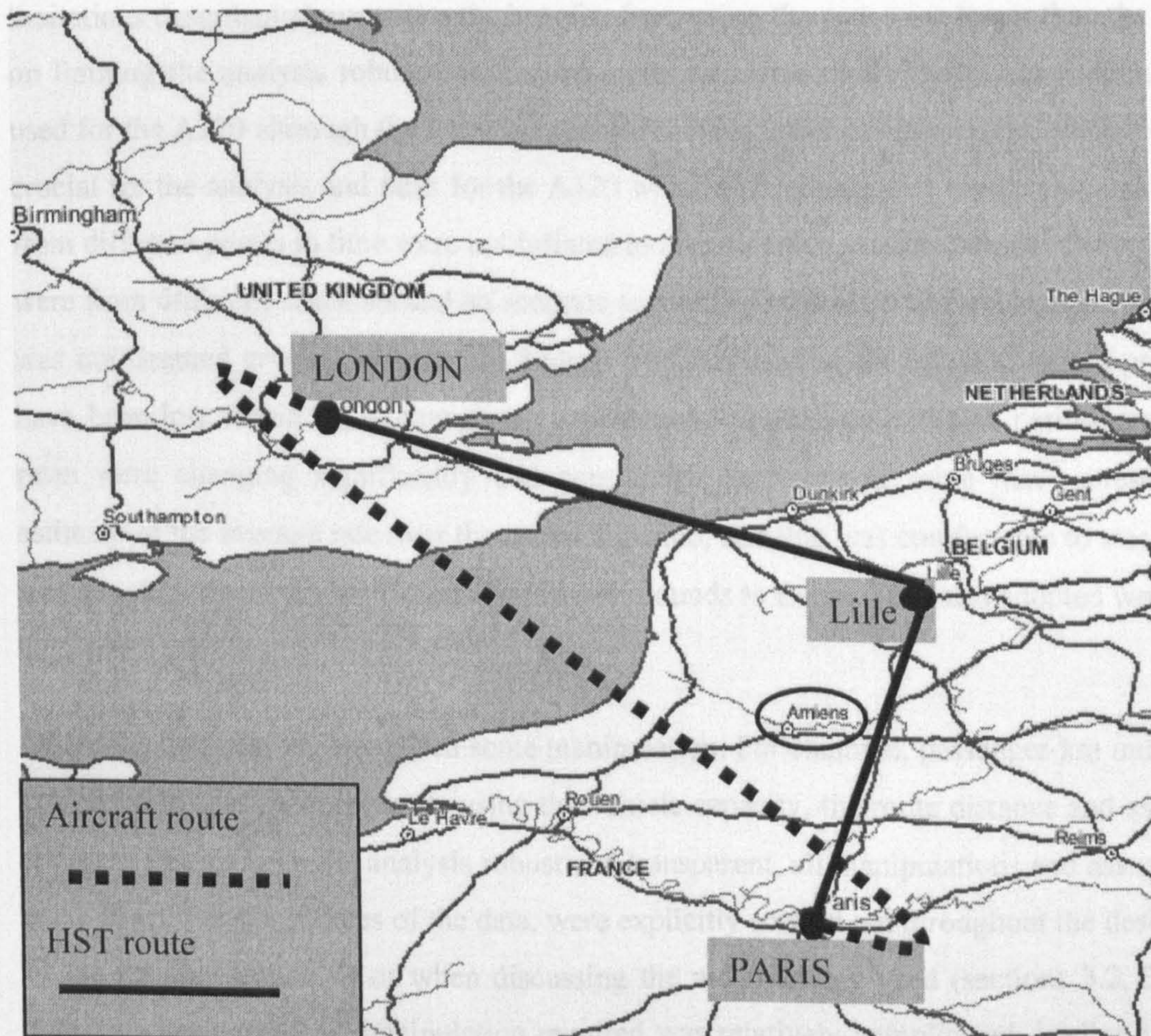
Aircraft	Airbus A319	Airbus A320	Boeing 757	Fokker 100	Airbus A321	EQV ¹	Boeing 737	Total
Seat/aircraft ²	124	150	178	109	185	--	128	Flights: 31 Seat/aircraft: 142
Daily flights ³	10	9	5	4	2	1	0	

¹ Equipment varies.

Source: ² Endres (2001); ³ BAA (2003a).

A special characteristic of the case study route is the exceptionally longer HST route compared with the aircraft route, and compared to other HST lines between major cities with respect to aircraft flights between them (Table 4). The main reasons are the fact that the HST line alignment from Calais (the French side of the Channel Tunnel) to Paris does not follow the shorter route but goes through Lille, and the location of the Channel Tunnel in respect of the direct line from London to Paris (Figure 8). As traffic builds up, running services from the Channel Tunnel directly to Paris, via Amiens, would probably become a viable alternative.

Figure 8: Map of the case study route



3.1.2.2 The empirical evaluation of operating airline and railway integration – data requirements

Apart from the methodological challenges of the empirical evaluation, the quality of the evaluation depended on the quality of data available. The scope and nature of this research dictated that the data used was ‘imported’ from other sources and was not produced for the research. This meant that a major obstacle was to find data suitable for use in this research which, at the same time, could be used in conjunction with data ‘imported’ from other sources. For example, data related to the aircraft had to be in the same units as the data found for the HST. Often, the different sources of data were from different points in time which might, for example for transport impact on the environment, reflect a different level of scientific understanding of the phenomena measured. In addition, for monetary data from different points in time, inflation had to be accounted for. The problem was further exacerbated by using data from different countries, hence different currencies.

In some cases, the best practical solution was to absorb into the evaluation some of the limitations described above, since the benefits from using the data were larger than the affect on limiting the analysis robustness. For example, estimates of B737 PM₁₀ emissions were used for the A320 although the latter is expected to have lower emission rates, since this was crucial for the analysis and rates for the A320 were not available. For practicality, estimates from different points in time were not inflated to present value, mainly because the estimates were from different countries and an accurate account of inflation was hard to achieve, and it was not deemed crucial. In part, any benefit from accounting for inflation would probably have been lost within the exchange rate calculations. During the research period, exchange rates were changing significantly and constantly. Therefore, a value that represents an estimate of the average rate over the research period, and that was comfortable to work with, was adopted to convert US Dollars and British Pounds to Euros. The rates adopted were £1 = €1.5 and \$1 = €1.

Often, the data available required some manipulation. For example, passenger-km units were converted to seat per route units using the vehicle capacity, the route distance and assuming a certain LF. To keep the analysis robust and transparent, all manipulations and assumptions used, as well as the sources of the data, were explicitly spelled out throughout the description of the results (section 4) or when discussing the methodology used (sections 3.2, 3.3, and 3.4). In some cases, the manipulation required was relatively complicated, leading to many assumptions. In these cases, sensitivity analysis was used to test the sensitivity of the results to the assumptions made.

The data used in the empirical evaluation of benefits from operating airline and railway integration can be categorized as operational data and scientific data. The former include data on vehicles capacities, travel time, OCs, etc., and can also be categorized as raw data. There is, in general, no ambiguity in such data, but that does not mean there are no methodological issues related to its use in this research. For example, the variations in the flight time between services on the case study route required careful selection of the value that was used in the analysis to prevent favourable conditions for one mode over another due to the selection of a specific travel time⁵⁹.

Scientific data is data that is published in other studies, and was derived following research and analysis, and transferred for use in this research. Estimates of the Value of Travel Time Savings (VTTS) and the environmental impact from emission of certain gases (in monetary and non monetary units) are examples of such data. Different studies evaluating the same phenomenon are likely to reach different results due to the different raw data they rely on, the different assumptions made, and the different circumstances in which the studies were performed. As a result, there is some ambiguity in the scientific data used in this research. In most cases, it is possible to trace only part of the raw data used, the assumptions made and the prevailing circumstances that influenced the results of each study used here as a source. While there are no solutions to these limitations, and no alternative to using data from other studies, these limitations must be acknowledged. Scientific data also represents, especially with regard to transport operation impact on the environment, the level of scientific understanding at the time the source study was carried out. This research must accept the level of scientific understanding of phenomena like transport operation impact on the environment and strive to make best use of current understanding. In this respect, a contribution to scientific understanding is expected following this research, by pointing out the most important aspects where further research is needed.

The evaluation of OC savings to airlines required ‘operational’ data only, and therefore this is a straightforward exercise that has no scientific uncertainty attached to it. However, the confidential nature of financial data meant that aggregate data concerning the aircraft OCs had to be used. For the HST, specific information, relevant to the circumstances of the analysis, was available⁶⁰.

⁵⁹ For example, travel time on a flight from Heathrow to CDG ranges from 60 to 90 minutes (BAA, 2003a). While these two are the extremes and occur for one or two flights a day, the most common journey time is 70 minutes, which was used, for example, in calculating CO₂ emission from aircraft operations (see section 4.3.2).

⁶⁰ See section 4.1.

The evaluation of travel time savings to passengers required data in both categories. The 'operational' data, mainly travel time for different services and different parts of the journey, was obtained from on-line timetables advertised by related operators or airports. When this was not available (e.g. for HST services from Heathrow), assumptions on travel time were used. Scientific data for the travel time analysis included VTTS estimates. Measuring the monetary value of travel time is a common practice in transport research and therefore there were ample estimates in the literature for use in this research, even for the aircraft mode where traditionally the use of such values is less common⁶¹. The challenge in this part was methodological, e.g. which estimates to use, and was not related to the availability of data.

The environmental analysis was a methodological challenge but also a challenge with respect to the data. Very detailed data on aircraft emission of different gases was available since this is part of the requirements to have aircraft engines certified. However, this data was not available for PM₁₀ emissions, recognised as an important pollutant to include in the analysis, and the data was available only for the landing take-off (LTO) cycle part of the flight⁶². This, as explained above, required some manipulation of the data available. The result was considered robust enough for the data to be used. In this part of the empirical evaluation, the use of operational data was also not straightforward. The main problem was to estimate the aircraft flight profile between Heathrow and CDG. Estimating how much time an aircraft flying from Heathrow to CDG spends climbing, cruising, and descending, after and the before the LTO-cycle, was critical for the analysis⁶³. In this case, information from the British Air Lines Pilots Association (BALPA) (Alder, 2004) was used to make the correct assumptions.

The evaluation of operating airline and railway integration was significantly affected by lack of appropriate data with respect to two issues. In the case of evaluating the benefits of noise reduction following airline and railway integration, comparable data for noise generated from aircraft and HST operation was not found. This seriously limited the evaluation of this (potentially) important outcome of mode substitution⁶⁴.

Lack of suitable data was even more of a problem for analysing the benefits of reduced delays following airline and railway integration. The research began by describing the congestion problem faced by the ATI and the result delays to services. Therefore, evaluating the punctuality of HST services in comparison to aircraft services was important. For the

⁶¹ See section 3.3

⁶² The part of the flight where the aircraft operates under the flight level of 915 meters including the time the aircraft operate on the ground (see section 3.4.2).

⁶³ Engine thrust is different for each stage leading to a different amount and mix of emission.

⁶⁴ See section 4.3.3.

HST services, data was not a problem⁶⁵. However, for aircraft services only data for delays on departure was available⁶⁶, but not for delays on arrival. The latter was required for the analysis since aircraft can recoup some of the delays on departure during the flight (although probably not as much on short haul flights), and since the advertised flying time accounts for possible delays⁶⁷. Hence, delays on arrival are of more concern to passengers, and were required in order to account for possible delays when comparing travel time. As a result, it was not possible to perform such an analysis in this research. Instead, different levels of delay were assumed.

In conclusion, the empirical analysis in this research required a variety of data but this, in most cases, was obtained in a sufficient manner whereas not to undermine the value and robustness of the analysis.

3.1.3 Conclusions

The development of the HST resulted, amongst other things, in competition between the train and the plane operators on routes where both modes achieve relatively similar travel time (city centre to city centre). However, the development of the HST also creates an opportunity for cooperation between the operators, airlines and TOCs, that would be beneficial to them, and to passengers and society. This aspect of mode substitution, which has not been thoroughly researched before, is the focus of this research. Its main elements are that the HST services begin at the airport, the airline and the TOC integrate their services, and the airline's HST service caters mainly for the transfer traffic market.

To evaluate the benefits of airline and railway integration, an empirical study on one case study route, Heathrow to Paris, was conducted. The empirical analysis was divided into two parts. First, benefits from the operation of airline and railway integration were evaluated and quantified using common evaluation methods. This included estimating OC savings to airlines, travel time savings to passengers, environmental benefits to society, and the potential to free runway capacity at the hub airport. The lack of evidence on the exact benefits of mode substitution, especially under a model of airline and railway integration, and the methodological challenge in quantifying such benefits, meant that this part became the focus of the research. In the second part of the empirical analysis, wider issues related to airline and railway integration on the case study route were considered, including expected benefits not covered in the first part. In this part, the context for considering the overall

⁶⁵ The same source that supplied the HST OCs data was used (see section 4.1).

⁶⁶ Through CODA's (Central Office for Delay Analysis) publications.

⁶⁷ See Appendix A.

effect of airline and railway integration was the possibility to increase capacity at the airport through rail services and not new runways.

The evaluation of benefits from the operation of airline and railway integration dictated many methodological challenges, mainly concerned with the evaluation of two different modes within one study. To overcome this, a specific evaluation methodology was developed (partly described above and in more detail in the next section) that was based on monetary and non-monetary quantification of benefits in **seat per route** units. The evaluation of environmental benefits posed another methodological challenge, and the methodology adopted is described in section 3.4.

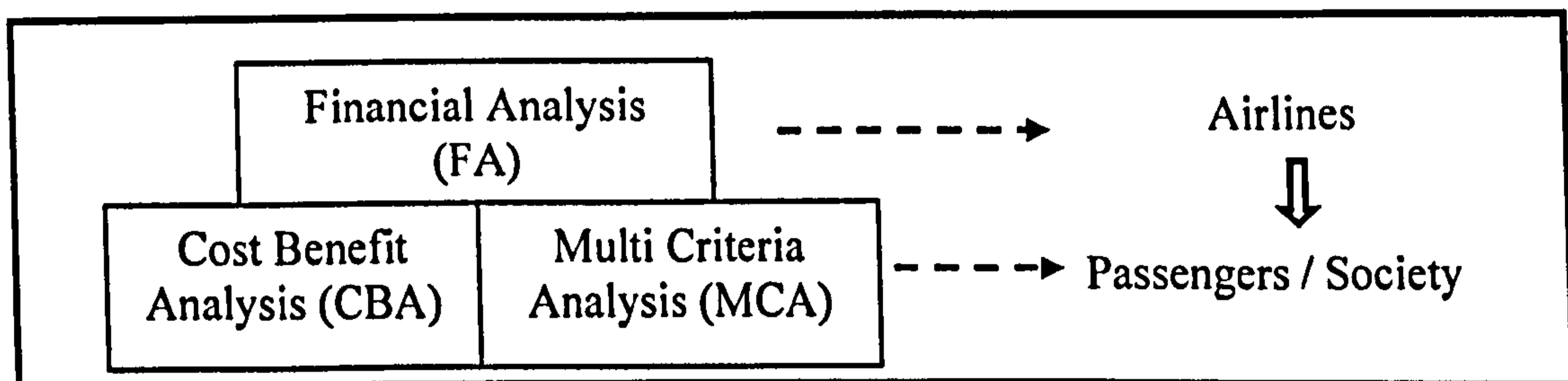
The contribution this research expects to make is therefore not confined to the evidence of benefits from mode substitution and the consideration of a new approach to mode substitution, but also includes a contribution to the evaluation practices of multi-modal studies and the evaluation practices of transport operation impact on the environment (mainly aircraft operation).

3.2 Social economic evaluation

Evaluation can be described as a “process which seeks to determine as systematically and objectively as possible the relevance, efficiency and effect of an activity in terms of its objectives” (Rossi and Freeman, 1993: 4)⁶⁸. “For the actual evaluation or project appraisal...the Transport Investment Evaluation Group⁶⁹ recommended the use of three tools, namely, financial analysis, cost-benefit analysis and multi-criteria analysis” (Giorgi and Tandon, 2000: 18). Accordingly, these tools were used in the evaluation of benefits from the operation of airline and railway integration.

Financial Analysis (FA) was used to evaluate the benefits to airlines, while Cost-Benefit Analysis (CBA) and Multi-Criteria Analysis (MCA), were used to evaluate the overall impact/benefits from the operation of airline and railway integration, including the benefits to passengers and society. FA is usually carried out separately from the social economic evaluation, since its objectives are different. However, the social economic evaluation, whether in the form of CBA or MCA, will include the FA. Usually, a choice between CBA and MCA is made, but in this research they are used in combination⁷⁰. Accordingly, the use of the three evaluation tools in this research is as outlined in Figure 9.

Figure 9: The use of evaluation tools in this research



Most transportation projects involve large amounts of investments that are expected to be recovered, usually over a long period of time, by the benefits of the project. Here, a change in operation was considered assuming, at the outset, that the required investments have taken place. Therefore, the evaluation of the operation of airline and railway integration did not consider the time element, and thus one-day operation or one service were enough to determine if the use of HST as a substitute for the aircraft is beneficial.

⁶⁸ Ex-ante evaluation, as opposed to ex-post evaluation, is usually referred to as appraisal. However, the term evaluation in this research refers to ex-ante evaluation only.

⁶⁹ Funded by the RTD programme in order to contribute to the development of standard guidelines for strategic and project evaluation in transport (Giorgi and Tandon, 2000).

⁷⁰ However, this is not unique to this research (see below).

This section supplements the previous one by providing the theoretical background on evaluation practices and explaining how the methods were used in this research. First, attention is given to the FA, then to the MCA and CBA, and finally the use of all three methods to present the benefits of integration is discussed.

3.2.1 The financial analysis

In broad terms, the objective of the FA, sometimes termed commercial analysis, is “to maximise the flow of money income received over time by shareholders from the firm...The objective of financial analysis is to assess the degree to which a project will generate revenues sufficient to meet its financial obligation and incentives for producers” (Giorgi and Tandon, 2000: 22). The FA in this research, however, considered only the ‘flow of money’ associated with aircraft and HST operating costs (OCs). The reference to OCs indicates that the expected benefit to airlines from the operation of airline and railway integration was reduction in OCs, and this was evaluated by comparing the aircraft and the HST OCs on the case study route.

In line with the methodology described above, OC benefits were measured per seat unit. In addition, it was assumed that from the passengers’ perspective the HST service was identical in all aspects to the aircraft, except for the difference in the mode used. Therefore, it was assumed that airlines’ revenues would not be affected by the change in mode used, only the OCs. The opportunity revenue, e.g. from using the freed aircraft on different routes or from using the freed slots for other routes, was not considered as a benefit from operating airline and railway integration⁷¹. Even though the investment in infrastructure was not explicitly included in the analysis, it was implicitly included through the charges airlines and railways pay for the right to use it. As a result, the OCs are influenced by the cost of infrastructure used, but not by the cost of (possible) new infrastructure.

The evaluation of OC savings to airlines required ‘operational’ data only. Public commercial companies⁷² are required by law to publish yearly financial statements which provide financial data on their activity, but such statements only provide aggregate data at the firm level. When a company has more than one product or service, and when there are many factors involved in producing these, it is not usually possible to use such data to estimate the costs associated with a specific part of a company’s activity. For instance: “railways normally supply a multiplicity of services. Various costs are incurred on behalf of the multiple outputs. It may be impossible to identify portions of total costs with a specific part

⁷¹ But was considered later. See section 5.1.1.

⁷² Companies whose shares are traded on the stock exchange markets.

of total traffic” (Waters II, 1985: 102). In other cases, if a company is private (not traded on the stock exchange market), such statements will not usually be available for the public, although they will usually exist for the company to keep track of its financial performance.

This research is concerned with a very narrow aspect of both the airline and the railway industries: the short haul flights on the one hand and the long distance inter-city HST services on the other. An airline or a TOC do not usually offer only these services, so data was expected to be a problem. Low cost airlines, like Easy-Jet or Ryanair, do operate only short haul services but they are less likely to adopt airline and railway integration since they do not operate from major hub airports where HST connection is likely to exist. In addition, their cost structure is different from the cost structure of major schedule airlines, which are the ones likely to adopt airline and railway integration. As a result, aggregate aircraft OC estimates, differentiated by aircraft model, across the industry were used. For the HST OCs, specific data was obtained on the HST services of a TOC. Due to commercial confidentiality, the data sources cannot be revealed.

OCs are usually divided between direct and indirect OCs. The direct OCs, in the case of transport operation, are the costs which can be attributed to a specific service, for example: fuel costs or track access charges. Indirect costs are all other costs, costs that it is hard to assign to a specific flight or train journey, for example marketing costs. In the analysis, only the direct OCs were of interest.

Under airline and railway integration, both the airline and the TOC continue to promote their own services separately, the integration is with respect to the supply of (some) services. In this case, an airline adopting integration would not save any “sales and promotion” expenses. In addition, it is necessary to distinguish between costs required to provide the seat capacity and the costs required to serve the passengers, such as catering and service personnel (ground and air stewards). The latter are assumed not to change when the mode used is changed, and therefore should not be included in estimating potential OC savings to airlines from mode substitution.

Doganis (2002a) provides a list of the traditional categories of airline OCs, and divides them between direct and indirect OCs. A similar division can be done for HST OCs (Table 7). To evaluate the OC benefits to airlines from the operation of airline and railway integration, the aircraft direct OCs need to be compared with the HST direct OCs.

In practice, the extent to which the methodology described above could be followed depended on the available data and the extent to which a breakdown of OCs to the categories in Table 7 was possible. This is described with the results in section 4.1.

Table 7: Categories of airline¹ and HST² operating costs

	Airline	HST services
Direct operating costs	<u>Flight operation:</u> Flight crew salaries and expenses Fuel and oil Airport and En-route charges Aircraft insurance Rental/lease of aircraft/crews	<u>Train journey operation:</u> Train driver salaries Fuel, oil and electricity Track access charge Train insurance Rental/lease of rolling stock
	<u>Maintenance and overhaul:</u> Engineering staff and costs Spare parts consumed Maintenance administration	<u>Maintenance and overhaul:</u> Engineering staff and costs Spare parts consumed Maintenance administration
	Depreciation and amortisation	Depreciation and amortisation
	Indirect operating costs	<u>Station and ground expenses:</u> Ground staff Building, equipment, transport Handling fee paid to others
<u>Passenger services:</u> Cabin crew salaries and expenses Other passenger service costs Passenger insurance		<u>Passenger services:</u> Train managers' salaries Other passenger service costs Passenger insurance
Ticketing, sales and promotion		Ticketing, sales and promotion
General and administration		General and administration
Other operating costs		Other operating costs

Source: ¹Doganis (2002a: 79); ² Based on data available (see section 4.1).

In conclusion, the FA is a relatively straightforward exercise without any scientific uncertainty. The quality of the FA depends almost solely on the quality of data available and the ability to differentiate between the direct and indirect OCs of aircraft and HST services. For airlines considering airline and railway integration, the results of the FA are the basis for any decisions. Social and/or economic benefits are not of their concern.

3.2.2 Social economic evaluation – Cost Benefit Analysis and Multi Criteria Analysis

CBA and MCA are concerned with socio-economic assessment and are “necessary to see if the project meets the broad programme objective” (Giorgi and Tandon, 2000: 18). Hence, they are used for a broader consideration of a project compared to the narrow financial aspect considered in the FA.

MCA, as opposed to CBA, is usually used when there is agreement that measuring the costs and benefits of a project in monetary units is either impossible or not sufficiently robust. Since the best way to compare different impacts is by measuring them in the same units, and monetary units seems to be the only option, CBA is probably the first choice of evaluation method when looking beyond the financial aspect of a project or policy. However, the uncertainties in measuring environmental impacts in monetary units and the challenges in estimating the value of time on multi-modal journeys suggest that the use of CBA in this research was problematic. As a result, both CBA and MCA were used.

Whether CBA or MCA is the preferred evaluation tool, and even when using CBA alone, the evaluation begins by measuring different effects of a project in different units (e.g. travel time in minutes, air pollution in emission, etc.) which are then converted to monetary units for the CBA. Thus, in essence, every evaluation process begins with a MCA.

3.2.2.1 Monetary evaluation methods: the Cost Benefit Analysis

CBA is an “analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value” (HM Treasury, 2003: 4). “Benefits are defined as anything that increases human well-being and costs are anything that decreases human well-being” (Giorgi and Tandon, 2000: 22). Human well-being is very subjective and depends on individual preferences and circumstances, and these are reflected in the monetary value assigned by individuals for any increase or decrease in welfare. This monetary value is known through the market price for goods and services or, when this does not exist⁷³, through Willingness To Pay (WTP) to increase welfare.

When ‘everything’ that increases or decreases humans’ welfare from a proposed project or projects is included in the CBA, reference is made to Social Cost-Benefit Analysis (SCBA) as opposed to CBA, or private CBA. “A private cost-benefit analysis only takes into consideration the pros and cons of a plan or project accruing directly and only to the actor concerned, while a social cost-benefit analysis adopts a broader scope by considering also all relevant positive and negative effects for those who are not directly involved (as a consumer or producer) in the plan or project under consideration” (Nijkamp and Blaas, 1994: 172).

The use of CBA in the evaluation of transportation projects is not different, in principle, from the above description. What is unique to the evaluation of transportation projects is that

⁷³ For example, there is no market price for clean air, but there is cost associated with maintaining the air clean.

the main category of benefits is travel time savings⁷⁴. To this, the need to measure the environmental impact of transport operations was added in recent years, but this is not unique to the transportation sector.

Most evaluations of transportation projects across the world are done using CBA⁷⁵. The results of the CBA are very clear to understand, and to interpret, and the results, once obtained, provide clear and unambiguous evidence of the project outcome in units that are understood by everyone and that allow comparison between the different costs and benefits of a project. This can explain the desirability of using CBA and the attempts to assign a monetary value to any effect or change the project might bring. For example, “assigning a financial [/monetary] value to emissions may provide better leverage for enhancing the efficiency and rationality of measures to tackle the environmental problems of global warming, air pollution, noise and so on” (Dings et al, 2002a: 21). For the same reasons, CBA was adopted in this research as the main evaluation tool.

Other than measuring the costs and benefits, CBA usually involves two additional elements: time⁷⁶ and welfare distribution⁷⁷. Neither of these elements was addressed in the analysis because airline and railway integration was not expected to lead to any significant changes in the distribution of welfare across society, and because one moment of time was considered⁷⁸. For more information on the CBA see Layard and Glaister (1994) and Brent (1996).

The distinction between costs and benefits is to some degree a matter of definition since in many cases the benefits are in the form of reduced costs, and costs can often be in the form of reduced benefits. Consequently, it does not matter if an impact that leads to an increase in welfare is counted as increased benefits or reduced costs. Thus, in the evaluation of the operation of airline and railway integration, the assumption that there are no costs (investments) involved means that only benefits are expected. However, all these benefits are the result of reduced costs (i.e. benefits of reduced OCs, reduced travel time cost, and reduced environmental costs).

Following from the above, the use of CBA in this research is as follows. Two journey alternatives are considered on the case study route, the aircraft and the HST journeys, and for each alternative the generalised costs of supplying a seat on the route are estimated and then

⁷⁴ Measured in monetary units.

⁷⁵ All countries in the EU use some form of CBA in the evaluation of transportation projects, but not all adopt MCA (Grant-Muller et al, 2001).

⁷⁶ This involves determining the time period over which to measure costs and benefits, and the discount rate to translate future costs and benefits to present value.

⁷⁷ Refers to the way the costs and the benefits are distributed amongst society

⁷⁸ The time element can be added at a later stage by multiplying the results over several years and applying an appropriate discount rate.

compared. If the HST alternative is less costly than the aircraft alternative, then the difference between the alternatives is the benefits from the operation of airline and railway integration. The generalised cost of a journey consists of the service OCs, the value of the journey travel time, and the environmental cost imposed by the journey.

In an analytical form, the CBA undertaken in this research can be described in the following way. The average general cost (AGC) of supplying a seat on the route is calculated for the aircraft journey (Equation 1) and the HST journey (Equation 2) The general cost function consists of a linear summation of the average operating costs (AOC) for airlines, the travel time cost (TTC) for passengers⁷⁹, and the average environmental cost (AEC) imposed on society by each seat supplied on the route. The difference between the aircraft and the HST AGC represents the benefits from integration (Equation 3).

$$1) AGC_{Air} = f(AOC_{Air}, TTC_{Air}, AEC_{Air})$$

$$2) AGC_{HST} = f(AOC_{HST}, TTC_{HST}, AEC_{HST})$$

$$3) \text{Benefit}_{INTEGRATION} = f(AOC_{Air} - AOC_{HST}, TTC_{Air} - TTC_{HST}, AEC_{Air} - AEC_{HST})$$

Where:

AGC is the Average Generalised Costs.

AOC is the Average Operating Costs.

TTC is the Travel Time Cost

AEC is the Average Environmental Cost.

Benefit INTEGRATION represents the net benefits from airline and railway integration

'Air' is journey by aircraft and 'HST' is journey by HST.

If the 'Benefit INTEGRATION' component in Equation 3 is positive, then airline and railway integration should be supported and adopted, at least on the operational level. However, if the 'Benefit INTEGRATION' component is positive but the 'Benefit INTEGRATION' function is not positive in all its components, i.e. airline and railway integration does not result in benefits to all stakeholders, then airline and railway integration should still take place but the beneficiaries from integration should compensate the losers. Since the decision to adopt airline and railway integration mainly lies with the airlines, compensation of the losers is crucial if the airlines are the losers (i.e. $AOC_{Air} - AOC_{HST}$ is negative). However, since airlines depend on the demand for their services, airline and railway integration would probably not take place if overall this is beneficial but not to passengers. Yet, if airline benefits are larger than the passenger disbenefits, then the airlines can compensate the

⁷⁹ The value of time is measured per passenger and then converted to seat using an estimate for each mode load factor (LF).

passengers through the fare mechanism. If, on the other hand, airline and railway integration proves overall to be beneficial but only to airlines and passengers and not for society, airline and railway integration is expected to take place without the beneficiaries compensating the losers⁸⁰.

In a way, this is a simple form of CBA as it does not involve the time, distribution, and cost/investment elements. This was adopted since the main challenge of the research was to evaluate the categories of benefits. Furthermore, if considering the investments required, mainly the HST connection to the airport, then many other benefits must be included (like improved access to the airport) which are not directly related to airline and railway integration.

3.2.2.2 Non-monetary evaluation methods: the Multi-Criteria Analysis

MCA, also called the multi-attribute method, “establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been met” (Dodgson et al, 2000: 17). Multi-criteria methods are used for ranking a choice of alternatives that are judged on the basis of broad criteria, and not on monetary basis only. Hence, each criterion is evaluated and measured in the appropriate units (for example, travel time savings are measured in minutes) which can be quantitative as well as qualitative.

The use of different units, selected to best describe each criterion, overcomes the limitations in converting any effect measured to monetary units, but it means that summation of the different criteria to reach one score for each option evaluated is not straightforward. In addition, MCA does not show if an action adds more to welfare than it detracts (ibid). Often, after the criteria have been decided, weights are given to each criterion depending on its importance and relevance. This practice, which can be done in numerous ways based on different methods, is the mechanism used to provide one result for each option evaluated. This practice, however, is always subjective since it requires ranking of the criteria in importance.

To present the results of the MCA, a score matrix, or table⁸¹, is created. “The matrix contains for all choice alternatives the numerical estimates of outcome of all relevant criteria, measured in their own appropriate dimensions...Next, by confronting the a priori specified

⁸⁰ The literature defines such a situation as a potential Pareto improvement, or the Hicks-Kaldor criterion, “which says that a project can be supported provided the gainers could, in principle, compensate the losers even if they do not” (Giorgi and Tandon, 2000: 22).

⁸¹ Also referred to as a ‘performance matrix’ or ‘consequence matrix’ (Dodgson et al, 2000).

weights set for the judgement criteria with the plan effect matrix, a ranking of alternatives may be obtained...[however] the use of weights is not strictly necessary” (Nijkamp and Blaas, 1994: 173).

In many respects, the MCA evolve to compensate for the disadvantages and limitations of the CBA. “Social cost-benefit analysis cannot handle entirely the assessment of public projects that have impacts with no direct monetary valuation. The natural solution is then to pursue the assessment analysis with a multicriteria methodology (MCA)” (Beuthe, 2002: 215-216). It is this recognition, that not all impacts of a transport project can be measured in monetary values, that led to the development of the New Approach To Appraisal (NATA) in the UK. The NATA is an application of MCA which takes account of those impacts that can be valued in monetary terms, through CBA, and those that cannot be valued in this way. Specifically, the NATA considers the following categories: environment, safety, economy, accessibility and integration. As stated, the traditional CBA is still used in the NATA and its outcome influences the decision.

With regard to the practice of assigning weights to the different criteria, Glaister (1999) states that “to give a numerical score [or weight] to more than one characteristic and then to trade one against the other (or against some cardinal quantity), on the basis of these numerical scores...is to pretend that what was assumed to be unquantified is, in fact, capable of cardinal measurement” (ibid: 230). It is, in other words, to decide if two minutes reduction in travel time is more or less important than a two ton reduction in CO₂ emission. For this reason, the NATA does not weight any of the various sub-criteria: “that is left for decision-makers. Attempts to do this would implicitly place relative values on the various impacts” (Price, 1999: 224-225).

The use of MCA to evaluate the benefits from the operation of airline and railway integration aims at offering an alternative to the uncertainties associated with the conversion of different effects to monetary units. The basis of the MCA evaluation is similar to the CBA, in that three categories of benefits were recognised and evaluated, namely OCs benefits to airlines, travel time savings benefits to passengers, and environmental benefits to society. For each category of benefits, the relevant criteria, and the units in which they are evaluated, were defined. As in the CBA, the evaluation separately considers the two journey alternatives on the case study route and compares them.

The criteria and units used in the evaluation are summarised in the summary table which is the product of the MCA (Figure 10). The choice of criteria was mainly dependent on the data available.

Figure 10: summary table of MCA for airline and railway integration

Category	Units	Aircraft journey (a)	HST journey (b)	Benefits (a-b)
Airline benefits				
Operating costs savings	€/seat			
Passenger benefits				
Travel time	Minutes			
Longest segment duration	Minutes			
Number of interchanges	No.			
Environmental benefits				
Local air pollution	Toxicity/seat			
Climate change	CO ₂ /seat			
Climate change	NO _x /seat			
Climate change	NO _x at altitude/seat			
Climate change	CO ₂ equivalent			

The results of the different criteria were not summed together in any form but were just presented in the summary table. This was to avoid ranking criteria by importance, and to allow consideration of more than one criterion for each category of benefits (in this case, any summation would lead to double counting). Since there is high uncertainty with the results of the environmental analysis, for example, the use of several criteria could help explain the results and their magnitude and reduce the uncertainties.

3.2.3 Evaluating the benefits from the operation of airline and railway integration - conclusions

This section discussed the use of FA, CBA and MCA to evaluate the benefits from the operation of airline and railway integration. The evaluation was based on all three methods using them in a straightforward manner and in a conventional way. To some extent, a simplified form of the conventional way was applied since the cost element (investments) and time element were not included.

Using FA, OC benefits were estimated, and separately using MCA and CBA frameworks, travel time benefits and environmental benefits were evaluated. Each category of benefits was evaluated independently based on the same principle: the difference between an aircraft journey and a HST journey on the case study route, in seat per route units, constituted the benefits. For travel time and environmental benefits, the results of the MCA were used as the basis for the monetary evaluation in the CBA. Hence, the CBA carries, at the outset, the uncertainties in the MCA results.

The concept of airline and railway integration as described in section 3.1 is not directly manifested in the evaluation. The evaluation, essentially, compares the aircraft and the HST in average units of impact (e.g. the average OCs per seat on the route), but the concept of integration is indirectly manifested by the fact that the HST journey begins at the airport and the service is provided to the airline passenger by the TOC and in cooperation, and not competition, with the airline. Furthermore, without integration, mode substitution would not have taken place, preventing any potential benefits. So although effectively the evaluation considers mode substitution per se, the assumptions surrounding the evaluation make it an evaluation of airline and railway integration rather than just mode substitution.

Despite the limitations of CBA, the advantages it offers (mainly the ability to appreciate and grasp the results⁸² and to compare between different categories of impacts) are not compensated for by the advantages of using MCA. Thus, MCA is not a complete or good enough substitute to CBA. A similar view is shared by others, for example Glaister (1999) and SACTRA (1999). “While there has been substantial progress in developing systematic and replicable non-monetary appraisal of environmental factors and the like, it is hard to see how these could be used as effectively as formal cost benefit results for analytical comparisons across different spending programmes at the highest level” (Glaister, 1999: 228). “Accepting that the full money valuation of all external environmental costs is not in prospect, it is still unavoidably necessary to make a case-by-case judgement about whether these costs are likely to be large enough to make the marginal social cost greater than the price, since this is critical to the whole analytical framework” (SACTRA, 1999: 18). In this research, it is still ‘unavoidably necessary’ to determine if net benefits exist or if, for example, environmental benefits are larger than any disbenefits to airlines and/or passengers.

One solution is “to separate (social) cost benefit and multicriteria analyses, and include in the latter mainly the criteria that cannot be easily assessed in monetary terms” (Beuthe, 2002: 216). This solution is the basis for the NATA where, in addition to the standard CBA, a MCA is used to evaluate the impacts not included in the CBA⁸³. However, this solution has some major shortcomings, especially with respect to impacts which can be evaluated in monetary units but to which there is still uncertainty regarding the robustness of such practice. The evaluation of environmental benefits in this research illustrates this point.

⁸² “Money values are better understood by everyone, citizens as well as decision-makers” (Beuthe, 2002: 217).

⁸³ In using this approach, care must be taken to avoid double counting in case the MCA considers (directly or indirectly) impacts included in the CBA. In the NATA, since there is no weighting of the criteria and no summation, there is no risk of explicit double counting.

Environmental benefits are one, if not the main, reason aircraft and HST substitution is promoted and are therefore crucial to estimate in this research. The monetary evaluation of such benefits is still very uncertain, due both to the level of scientific understanding of how the environment is altered by human activities and the estimation of the cost of damage caused by these activities, but nevertheless such evaluations are increasingly used. Providing evidence that airline and railway integration would lead to a reduction in NO_x emission by X units is important but cannot be used to justify Y investments, or Z travel time losses to passengers. At the same time, a decision to promote airline and railway integration because it will result in €X reduction in damage associated with NO_x emission might be completely misleading and its robustness questionable.

To resolve this problem, the following approach was adopted. The conclusions are based on the CBA results, but each category of benefits evaluated in monetary units is accepted only if it is consistent with the MCA results, otherwise it is excluded from the CBA⁸⁴. This approach has its limitations, especially when the MCA results indicate a different magnitude of impact⁸⁵, but it is still considered a better approach than other practices. It is considered better than, for example, the NATA approach of estimating environmental benefits in non-monetary units since this does not provide information that can be usefully used in the decision-making process⁸⁶. It is also considered better than including environmental benefits only in the CBA, a move supported by HM Treasury in its Green Book on evaluation (HM Treasury, 2003) and consequently adopted in the evaluation of transport projects, since such practice can be misleading⁸⁷.

Evaluation of transportation projects and policies usually also consider wider economic and social impacts. The first examine a possible increase in GDP and employment following investments in transport⁸⁸ and the second if such investments are likely to benefit or disbenefit specific groups in society, in other words lead to redistribution of welfare. Such

⁸⁴ This means, if the CBA shows positive monetary benefits, but the MCA suggests negative benefits (a possible outcome when the benefits/disbenefits are a comparison of two options), the CBA results are ignored.

⁸⁵ In this case, it is harder to decide whether to accept the CBA.

⁸⁶ Furthermore, the Guidance on the Methodology for Multi-Modal Studies (GOMMMS) (DETR, 2000e) states that the NATA brings information from the monetary (CBA) and non-monetary (Environmental impact assessment) analyses together to give a fair and unbiased overall description, without attaching importance to any type of effect expressed in monetary terms over those which cannot be monetised. But in making a decision, weights are implicitly attached to each effect and 'money speaks louder'.

⁸⁷ For example, at one stage of the analysis, the MCA suggested a reduction in local air pollution from airline and railway integration but the CBA showed negative benefits from reduced local air pollution (see section 4.3.1).

⁸⁸ See SACTRA (1999) and Banister and Berechman (2000). As with environmental impacts, there is debate if these can be, and should be, measured in monetary units. The DfT currently does not recommend measuring such impacts, like job creation, in monetary units (LTT, 2002).

impacts were not expected to be a result of airline and railway integration and therefore were not included in the evaluation. Wider economic benefits were not expected since there will be no major change in the transportation infrastructure network from linking Heathrow to the CTRL. This also holds for airline and railway integration in general since one of the assumptions is that the HST line on the route is available, and only the link to the airport is missing. Social impacts were not expected since there would be no change in the mix of users following airline and railway integration. Land use and safety impacts were also not considered to be significantly affected by airline and railway integration and were therefore not included in the evaluation.

In summary, the use of MCA and CBA as the basis for conclusions in this research was different from the conventional way that uses either one separately or one (CBA) within the other (MCA). The approach in this research was based on the realisation that there is still no good alternative to the advantages of monetary evaluation but its limitations mean care must be taken when using it. This is done by using the MCA to support the CBA results or to disregard them. It is accepted that evaluation, and even more so decisions based on the evaluation, would always remain subjective, to some degree, but the approach taken in this research is believed to be more robust and transparent than simply showing the CBA results. At the same time, it provides the benefits of the CBA.

3.3 The Value of Travel Time Savings (VTTS)

The extensive use of CBA in the evaluation of transport projects, and the part travel time savings play in benefits from investing in such projects, led to an extensive research on the monetary value of time. Accordingly, travel time saving “is the most important benefit category in nearly all transport infrastructure or related projects” (Wardman and Waters II, 2001: 85). Unlike measurement of environmental impacts in monetary units, the measurement in monetary units of the Value Of Time (VOT), also referred to as the Value of Travel Time Savings (VTTS) which is adopted in this research, is widely acceptable and, it seems, is not questionable. Nevertheless, while there is general agreement concerning the theory of evaluating the VTTS, its empirical application still faces some difficulties. By its nature, this research is concerned with the empirical use of the VTTS more than with the theory behind it. Furthermore, in the context of this research, the use of VTTS estimates is the focus while the way these estimates were obtained is not. Accordingly, this section focuses on the use of VTTS in empirical evaluation in general, and in multi-modal evaluation in particular.

3.3.1 The theory of the value of time

The concept that a rational consumer strives to maximize his/her utility from consumption of resources/commodities, subject to his/her available resources is the basis for the consumer's economic theory. One of these resources is time, which is used during the course of consumption. For efficient use of the limited available time resource, the consumer needs to allocate time between activities in a way that maximizes utility. Therefore, time in itself has a value of utility for the consumer.

Other than time, consumers also need financial resources to be able to consume and engage in some activities. The financial resources are gained by allocating time for work activity in return for a wage. When not working, the range of consumption activities a person is engaged in is termed leisure. Except for work and leisure, a person also allocates time for intermediate activities, which are undertaken not for their own sake but as a necessary input to engage in other activities. Travelling is considered as an intermediate activity and therefore, any amount of time devoted to travelling is assumed to have a negative utility because it is not a person's desire to devote time for travelling but a necessity in order to engage in desired activities⁸⁹.

⁸⁹ This characteristic of travelling as an activity leads to referring to travel as a 'derived demand'.

Assuming there are three groups of activities, as described above, any reduction of time spent on intermediate (travelling) activities is used for either work or leisure. To begin with it was assumed that the marginal value of time spent in an activity is the wage rate as this is the opportunity cost (shadow price) of assigning time to any activity other than work. In other words, by choosing to spend the extra time available in leisure activities we give up work, thereby losing the wage rate. However, as the theory of the VOT evolved there was recognition that the value of leisure time is different from the wage rate, leading to separation between the VOT devoted to work activities and leisure activities (see MVA Consultancy et al, 1994; Mackie et al. 2001). This is now common practice in almost all studies on the VTTS.

Accordingly, there is different (negative) utility from time spent travelling during work or outside work. This utility is valued at the opportunity cost of the time spent travelling since any reduction in travel time can be used for either work or leisure activities. If travel time saved is productively used for work, and given that the marginal product of labour is reflected in the costs of employment, then the gross wage is a good measure for the value of saving time on work journeys (Bristow and Nellthorp, 2000). On the other hand, if travel time saved is used for leisure activities then its value needs to be deduced through surveying as there is no market for leisure activities that produces a value parallel to the wage rate in the labour market⁹⁰.

Empirical evidence shows that the VTTS depends not only on whether the journey is part of work or not but also on the purpose of travelling (e.g. commuting is often added to the work and leisure categories), socio-economic characteristics of the traveller (the VTTS is higher for rich people than for poor people), journey characteristics (e.g. distance travelled, duration of journey, etc.), and, most important in this research, the mode used. For best estimation of the VTTS, each person's value of time in each possible travelling option should be calculated. This, of course, is not realistic. Hence, when performing a survey to find the VTTS, a compromise needs to be made between accuracy of the values (many categories) and the survey complexity and cost.

To summarise, “[The VTTS] should be valued at the opportunity cost, that is at the value of what can be done with saved time, or of what must be forgone if time is spent travelling rather than doing something else. This value is what the relevant traveller would be willing

⁹⁰ There are two distinct methods to estimate the VTTS for non-working (i.e. leisure) journeys. The Revealed Preference (RP) method is to observe the actual behaviour of people in choosing between different travelling options taking into consideration the cost they paid for their journey. The Stated Preference (SP) method is to ask individuals to place a value on different hypothetical travelling options and conditions. Hensher (2001) reviews the RP and SP methods for measuring the VTTS.

to pay for time savings, or would be willing to accept in compensation for lost time” (Evans, 1999: 1). For extended theoretic background on the VTTS, see for example MVA Consultancy et al. (1994) and a special issue of Transportation Research Part E, volume 37, 2001.

3.3.2 The use of the value of travel time savings in public transport

Traditionally (social) economic evaluation was performed for road projects. Accordingly, most of the VTTS estimates are for the private car⁹¹. As evaluation became standard practice when considering transport investments for other modes, estimation of VTTS for public transport modes became common. Thus, we have values for bus, underground, train and aircraft journeys, although for aircraft journeys values are harder to find, perhaps indicating the lesser extent to which economic evaluation has been performed for this mode⁹². Journeys by public transport are different from journeys by car in many ways. These influence the VOT and need to be accounted for when estimating the VTTS. In practice, these differences usually make the application of the VTTS in public transport empirically more complex. Since this research is concerned with public transport it is important to highlight and address these differences in the context of empirical evaluation.

The reason for different VTTS for different modes might be the result of the different income and social characteristics of the users of each mode (Mackie et al, 2001). Poorer people tend to travel by bus while richer people tend to use the car. This implies that for the same people, the VTTS is expected to be the same on different modes. In this research it would lead to assigning the same estimate for the flight and HST part of the journey. However, empirical evidence also shows that the same people do value their time differently on different modes even during the same journey. For example, Furuichi and Koppelman (1994) found different VTTS for the access to airport and flight parts of a journey. One explanation might be that the attributes of the mode, other than the ones affecting travel time (e.g. safety and comfort attributes), affect the VTTS as well. Another explanation could be the circumstances in which the mode is used, for example, the risk of missing a flight or a train service that a person must use probably leads to a higher VTTS on the access mode

⁹¹ Interestingly, in the UK much of the evaluation procedures for transport investments (in any mode) is based on the work of the Standing Advisory Committee on Trunk Road Assessment (SACTRA).

⁹² See Bråthen et al, 2000.

whatever it is⁹³. Whatever the explanation might be, the evidence suggests that a distinction by mode is necessary when estimating the VTTS.

However, the EU favours the use of the same VTTS for all modes when the journey is not during work time. The reason is “practical benefits of using a single value: in particular, the clear impression of comparability between appraisals of infrastructure investment in different modes” (EUNET, 1998: 2.6.1)⁹⁴. Such an approach ignores the fact that there are likely to be differences in the VTTS for different modes, and these differences should be accounted for when comparing between modes. The EU favours the use of a single value also to help overcoming equity problems, but in this research the same people ‘choose’ between the two options of travel and therefore equity problems are not expected to arise following airline and railway integration. Furthermore, the EU advocates the use of different values for time spent on different modes during work time because “differences exist between modes in terms of the ability to work in transit” (ibid: 3.2.7). These differences are probably also valued by passengers travelling for non-work purposes.

Another element that differentiates journeys by public transport from journeys by car is the relatively large amount of time spent outside the mode used for travel. This time is spent accessing and egressing the transport service, interchanging between services, and waiting for the service (either because the passenger arrived too early or because the service is delayed/late), and is termed Out of Vehicle Time (OVT), as opposed to In-Vehicle Time (IVT) the time spent on board the transport mode. In general, the OVT is considered to be divided between walking and waiting time.

OVT estimates are usually presented as a proportion of the IVT VTTS of the mode they relate to⁹⁵. There is a tradition, assumed to be for simplicity reasons, to value walking and waiting time at twice the IVT for non-business trips (Mackie et al, 2001, Wardman 2001a), although other estimates are used as well. In addition there are other elements of IVT, other than walk and wait, which are evaluated. Wardman (2001a), for example, estimates the VTTS of ‘access time’ to public transport at 1.81 IVT.

⁹³ The ‘price’ of missing the connecting service, and as a result the VTTS, is expected to increase as the frequency of the service decreases and as the costs associated with missing the service (e.g. losing the ticket and buying a new one, missing an important meeting, etc.) increase.

⁹⁴ It might be assumed that the EU considered cases where a road project is compared with a rail project, for example, i.e. car versus rail modes, but it did not consider projects in which two modes are used during the same journey. In this case there is no competition between the modes and hence no risk of bias towards one mode.

⁹⁵ The only explanation found for this is as follows: “Transport analysts and planners can more readily interpret such values than monetary values and they are also more transferable both spatially and temporally” (Wardman, 2001a: 109).

In the context of this research, the most important element of the OVT is the interchange, or transfer, time. The reason is that one of the differences between the aircraft journey and the HST journey is that the former requires an extra transfer (at the destination airport between the flight and the egress journey to the city centre), and the high VTTS for interchange time. The VTTS of interchange time can be assumed to be at least twice the IVT if it entails only walking between services and waiting for the next service. However, this does not account for the inconvenience of interrupting the journey (for example when the passenger already had found a seat, was reading, working or resting), the risk of losing the connection service, the extra physical effort especially when carrying luggage, and the extra stress in cases when the passenger is unfamiliar with the station. This implies that interchange time is likely to be higher than the factor of twice the IVT assumed for walking and waiting time⁹⁶.

The nature of measuring the OVT means that on journeys with an interchange between different modes, and assuming each mode has a different VTTS, the OVT VTTS must be attributed to one of the modes. This, it seems logical, should be the mode the passenger transfers to. It can be assumed that from the passenger's point of view the journey begins again at the moment of arrival to the interchange point by accessing the next mode. Hence, the mode the passenger transferred from has no influence anymore on the VTTS, but only the mode the passenger transfers to. This was the practice adopted in this research.

Travel time is usually considered as wasted time, hence the benefits from reducing the travel time. However, different activities which can be undertaken while travelling can reduce the extent to which travel time is a wasted time. Mokhtarian and Salomon (2001) contest the belief that travel is always a derived demand and that the personal utility from travelling is always negative. Amongst the reasons they state for the desire to travel for the sake of travelling are the activities that can be conducted while travelling. They add that "in fact, some people prefer public transportation to the private auto precisely because not having to operate a vehicle offers the opportunity to engage in other activities while travelling" (ibid: 702). The implications of a positive utility from travelling for transport policy are immense. In the context of this research it is enough to suggest that passengers faced with two options of travel, both with the same travel time (and cost), will probably prefer the option that offers greater ability to engage in different activities while travelling. "The 'cost' to the individual of travel time is reduced as travel time is converted into activity time...encouraging greater use of modes that best enable en-route activities to be undertaken" (Lyons, 2003: 6).

⁹⁶ This implies that one minute of on-board time equals at least two minutes of interchange time. The implications of this in terms of where efforts to save time should be focused on are clear.

Therefore, when comparing two different modes, the extent to which they allow to ‘engage in other activities’ should be reflected in lower VTTS. “Appraisals should take into account the reality that some modes of transport, particularly long distance trains, may allow travelling time to be used productively whereas other modes of transport do not. In effect, time spent travelling may be partly converted into working time if a passenger uses a high speed train rather than (for example) an aircraft” (CfIT, 2004: 52-53). The CfIT (2004) notes that this has not been taken into account in British evaluation, and although this has been applied in Scotland and Spain, for example, no estimate on how to account for this was found, and accordingly this was not accounted for when estimating the VTTS⁹⁷.

There are several other aspects related to the empirical application of the VTTS that are important to consider. Two of them are travel time reliability and the VTTS over time, both of which are not considered in this research as explained below. Many studies estimate the elasticity of the value of time with respect to GDP since as income changes, the VTTS is expected to change (see for example: Mackie et al, 2001). However, since the evaluation in this research has no time element such estimates are of no concern. Perhaps more important is the value of travel time reliability.

Travel time reliability can be defined, in the context of public transport, as the discrepancy between the advertised journey time (departure and arrival times, and more likely the latter) and the actual journey time. “Variability [in travel time] introduces uncertainty for travellers so that they do not know exactly when they will arrive at a destination...Travel time variability (or the uncertainty in trip journey time) is clearly an added cost to a traveller making a given journey” (Noland and Polak, 2002: 40)⁹⁸. Evidence suggests that “in some situation, travellers seem to value more highly a reduction in variability than in the mean travel time for that journey, and elasticities with respect to variability appear to be high” (Bates et al, 2001). Evidence found by Rietveld et al (2001) when examining public transport journey chains, confirms this and provides empirical estimates. Accordingly, in this research comparing the level of delays for aircraft and HST services would allow to add a travel time reliability factor to the VTTS analysis. As stated above, there was not sufficient data to conduct such an analysis in this research.

Another important, and controversial, aspect in empirically evaluating the VTTS is the treatment of small travel time savings. In a developed transportation network, transportation

⁹⁷ Instead, this was accounted for within the MCA framework.

⁹⁸ The average discrepancy between timetable and outturn is termed *punctuality*. In the UK rail industry the terminology defines *reliability* according to whether the train runs, reserving *punctuality* to denote whether, if it runs, it arrives at its final destination on time – or within a margin thereafter (Bates et al, 2001).

investments often result in small travel time savings, and the question is whether a person can effectively use, or even notice, such travel time savings. If the answer is no, then these travel time benefits should not be used to justify a project. Two approaches to treating small travel time savings in evaluation exist: the Constant Unit Value (CUV) approach which assigns the same value to small and large travel time savings⁹⁹ and the Discounted Unit Value (DUV) in which the benefit from each unit of time saved is reduced (possibly to zero) below one or more critical thresholds. Welch and Williams (1997) carried out an empirical study and showed that using some kind of DUV rather than CUV method can reduce the benefits of travel time savings by as much as 90% when the threshold was set at two minutes. The study indicates that there is no single internationally accepted convention for the evaluation of small travel time savings, but “the Constant Unit Value approach is currently dominant” (ibid: 252). Accordingly, the CUV approach is adopted in this research although there are convincing arguments against it¹⁰⁰.

3.3.3 The use of the value of travel time savings in this research - conclusions

Passengers are one of the three stakeholder groups expected to benefit from the operation of airline and railway integration, mainly through reduced travel time. These potential travel time savings were converted to monetary units, to allow for appreciation of the benefits and for comparison with other benefits, using VTTS estimates. While the theory of applying monetary values to travel time savings is relatively founded, its empirical application is very often ambiguous.

The evaluation of travel time savings benefits from airline and railway integration on the case study route began by evaluating the travel time of each alternative and dividing it between the different parts of the journey e.g. flight time, transfer time between aircraft and egress mode, egress journey time, etc. Then, VTTS estimates were assigned to the travel time. The problems with the application of the theory of VTTS, highlighted above, were addressed in the empirical analysis by assigning different sets of estimates, according to different practices (e.g. one estimate across different modes, and mode specific estimates), and examining their influence on the results and relevance to the circumstances in this research. In all cases, a distinction was made between leisure and business travel.

⁹⁹ This means, the same value per minute saved.

¹⁰⁰ One argument, although not directly related to the monetary evaluation of small travel time savings, is that the identification and measurement of small travel time savings following a change in the transport network is problematic.

In empirical studies, it seems, three sources or types of VTTS estimates are used, from a survey specifically performed for a specific study, using VTTS estimates from surveys done for other studies, and based on the wage rate appropriate for the study's population, or a percentage of it. The second type of estimates, the ones obtained for other studies, is used in this research.

The nature of the evaluation in this research meant that a specific survey, to estimate the VTTS, would be the best option. Beside the fact that this was not possible within the scope of the research, there were other obstacles to doing so, mainly because the journey and the passengers are of international nature. Passengers expected to benefit from travel time savings on the case study route are likely to be mainly American and/or French¹⁰¹, each with different VTTS depending on the country of origin. One solution to this was the use of the EU recommended VTTS¹⁰². As noted above, the evaluation was also influenced by the exchange rates used¹⁰³ and by not considering inflation to bring all estimates to present prices. The results of the travel time benefits analysis are presented in section 4.2.

¹⁰¹ The case study route assumes the passenger arrives to Heathrow from, for example, New York and then transfers to a service to Paris.

¹⁰² There was no estimate at a more aggregate geographical coverage.

¹⁰³ In order to convert all estimates into Euro units. Exchange rates used: £1=€1.5, \$1=€1, SEK1=€0.11, NOK1=€0.13

3.4 Measuring the impact of transport operation on the environment

Many of the studies that consider plane and train substitution state the environmental benefits from changing the mode used as the main reason for supporting mode substitution. For example, “the Head of the European Commission’s Airport Policy Unit in DG VII wants to see the [ATI] environmental capacity problem alleviated by a shift from air to rail” (AACI, 1992 in: Caves and Gosling, 1999: 58). The IPCC report states that “substitution [of aircraft] by rail and coach could result in the reduction of carbon dioxide emissions per passenger-km (IPCC, 1999: 12)¹⁰⁴. Accordingly, one of the main contributions of this research is the evaluation and measurement of the benefits of a reduction in environmental impact as a result of airline and railway integration.

The results of the evaluation are presented in section 4.3. This section provides the theoretical background and describes the methodology adopted for the evaluation of environmental benefits from airline and railway integration. It begins with a general discussion of the methodology to evaluate HST and aircraft operation impact on the environment, followed by a specific discussion on the evaluation of what is considered to be the most damaging effects of aircraft operation, and hence the main benefits from mode substitution. These are Local Air Pollution (LAP), climate change, and noise¹⁰⁵. Following the methodology described in 3.1, the environmental impact from the aircraft journey includes the surface journey from the destination airport (CDG) to the destination city city-centre (Paris city-centre).

3.4.1 Evaluating the impact of transport operation on the environment

In order to evaluate the impact of transport operation on the environment, a certain procedure (outlined in Figure 11) should be followed. The first step/requirement is to measure the level of transport activity (mode used, types of vehicles, service frequency, etc.). This is the only precise step in the sequence of steps shown in Figure 11. From this point, when moving along the pathway, described in Figure 11, the level of scientific understanding is reduced

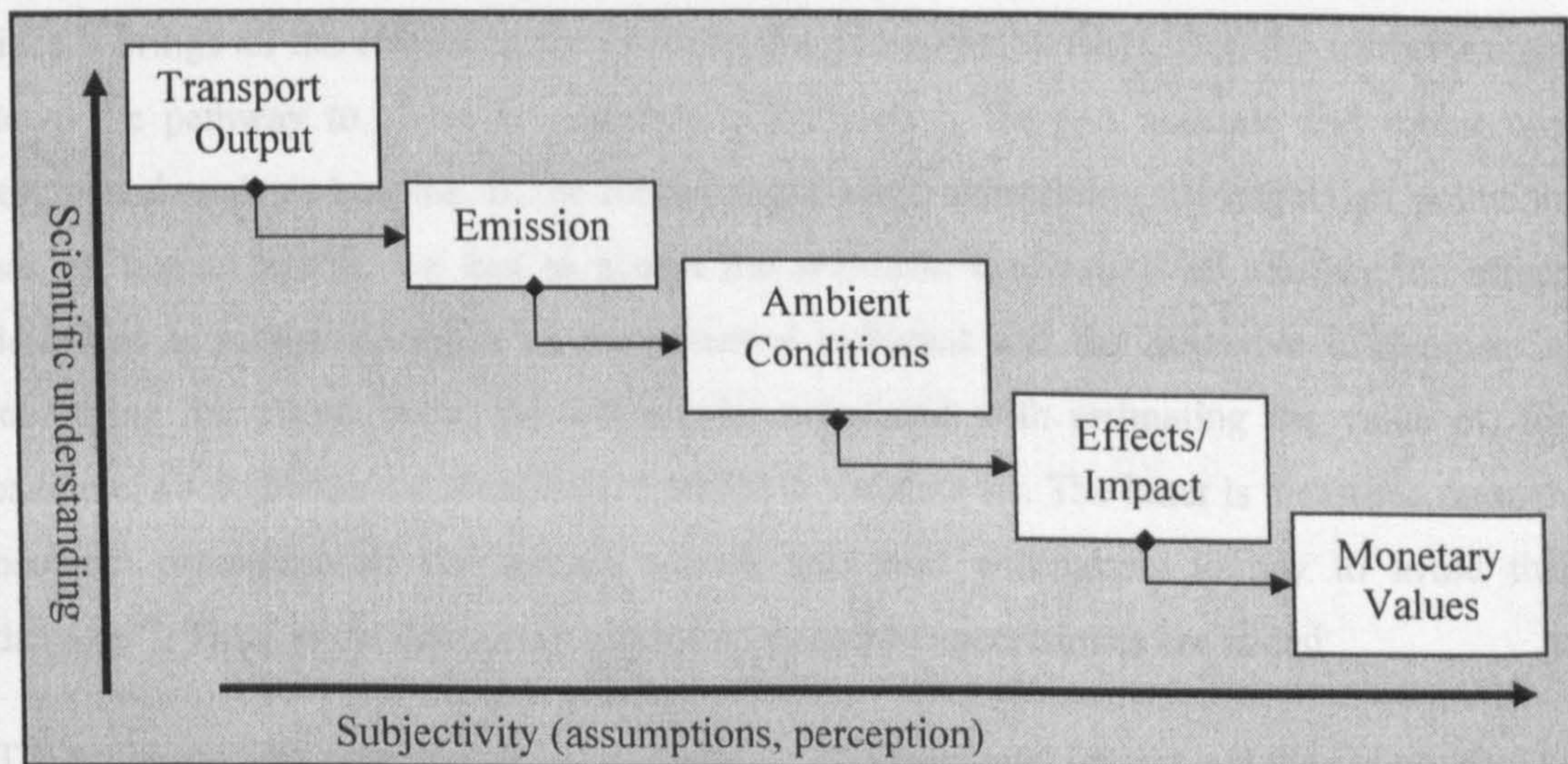
¹⁰⁴ For a list of studies which consider the HST to be ‘environmentally’ better than the aircraft see section 2.1.5.

¹⁰⁵ Other environmental effects of aircraft and HST operation are: land take, soil and ground-water contamination, acid-rain, habitat, heritage, and severance. These were not considered to be significantly affected by airline and railway integration, nor to change the relative environmental comparison between aircraft and rail (CfIT, 2001a).

and subjectivity is added into the analysis as a result of the different assumptions that it is necessary to make. The next step is to measure emission during the journey. This task depends on the scientific knowledge of the relationship between energy sources used, amount of energy consumed, and the resulting emission. In the case of fossil fuels, the temperature at which combustion occurs is an important factor in determining the emission profile, which adds another obstacle for an accurate estimation of emission. However, measuring just emission is often not enough because of differences in the damage each pollutant inflicts on the environment, which depends on the pollutant's character, its source and ambient concentration (Colvile et al, 2001).

The next step therefore, measuring ambient conditions, is vital for an accurate estimation of environmental impact. To be able to screen the effect of transport emissions on the environment from the overall existing environmental conditions (the natural existence of gases in the air plus gases resulting from other human activities), the ambient conditions of the pollutant in question must be considered. If the ambient concentration of a specific pollutant is already very high, then emission of this pollutant from transport is not likely to increase the environmental impact. Ambient conditions are changing constantly due to weather conditions (mainly wind and precipitation), making it almost impossible to determine the ambient conditions when emission occurs. Indeed, most empirical studies trying to measure the impact of emission on the environment skip this step.

Figure 11: The pathway to evaluate transport operation impact on the environment



Source: Based on Schipper (2000).

The next step in the pathway is to define the effects any pollutant has on the environment, the dose-response or source-receptor relationship. On top of the scientific challenge of establishing the exact effect each pollutant has on the environment in general, and on human health in particular, there exists a limitation in measuring and quantifying those effects and

attributing the effects observed to a specific pollutant. Environmental impact is usually measured in terms of the effect on human mortality and morbidity, although emission can affect habitats, vegetation and wildlife as well. To determine or measure how many more people will be admitted to hospital because of an increase in SO₂ emissions from transport, for example, is neither a easy nor a precise task. Yet, such estimates and measurements are done constantly and provide estimates of environmental impact from transport operation.

Comparing different impacts of transport operation, e.g. noise and NO_x emission, is like, in economists' jargon, 'adding apples and oranges'. Because aircraft can produce noise and emit NO_x, a common denominator for all the affects on the environment needs to be found. This is usually the monetary value of the impact, i.e. the cost of damage (real and perceived) caused by transport. The damage costs also include the costs incurred when trying to avoid or minimise the damage caused by environmental pollution. For example, Governments may decide to impose zoning restrictions on land that is subject to excessive noise. Therefore, costs of damage/nuisance include avoidance/adaptation costs. It is different, however, from the costs of abatement measures, which are measured as environmental costs. The latter means that the result of extra emissions does not lead to extra environmental damage (cost), but to additional (cost of) abatement measures (Dings et al, 2002a). The costs referred to in this research are the damage costs.

It seems sometimes that measuring the monetary value of (environmental) impacts is the ultimate goal when trying to evaluate the effect human activities have on the environment since it brings all the effects on the environment to a common basis. But, the further we go down the pathway to arrive at monetary quantification, the less accurate and robust our results and analysis become. In the former stage, when considering the impact air pollution has on human health, we had to accept the scientific uncertainty of whether the effect described is really the result of the assumed pollutant and the objective difficulties in measuring the effect. Now, the subjectivity associated with estimating the value of, for example, air pollution and its effects, is added to the analysis. The latter is measured through peoples' perception of the damage caused and their willingness to pay to avoid this damage¹⁰⁶. Thus, at the final stage, economic valuation uncertainties are added.

The problems with placing a monetary value on environmental impact and the controversy of such a practice are apparent in the UK. The CfIT (2004) study on the evaluation of HSTs emphasizes that the new SRA appraisal guidance, consistent with the new Green Book, states that monetary values should be placed on environmental impacts. It further states that "the failure

¹⁰⁶ For a detailed description of environmental evaluation methods see Daniels and Adamowicz (2000).

to put monetary values on environmental impacts could have been considered one of the greatest shortcomings in the British approach to appraisal in the past, but the new guidance brings Britain into line with best practice in other Countries” (CfIT, 2004: 6.10, emphasis in original text). In contrast, the Environmental Audit Committee in its Ninth Report states that “the HM Treasury/Department for Transport document *Aviation and the Environment* tries to calculate the totality of environmental costs arising from aviation. The attempt to do so may be fundamentally flawed” (Environmental Audit Committee, 2003: 4). It adds “we [the Environmental Audit Committee] were critical of the Treasury’s increasing emphasis on monetarisation where these costs are intrinsically difficult to calculate” (ibid: 17). Likewise, this research also faces a conflict between placing a monetary value on the environmental benefits from airline and railway integration on the one hand and accepting that this could lead to questionable and not robust results on the other hand¹⁰⁷.

3.4.1.1 Evaluating the impact of aircraft and HST operation on the environment in this research

Recognising the importance of putting a monetary value on the environmental affect of airline and railway integration means that the pathway described in Figure 11 should be followed. That is almost impossible to follow in practice, even more so within the scope of this research¹⁰⁸. Instead, the methodology adopted in this research for the empirical analysis is a three-level comparison between the modes in terms of emission, impact, and monetary value of the impact. Thus, Figure 11 is partially followed. The basis for estimating emission is transport output (seat per route), which in turn is the basis for estimating both the impact and the monetary value of the impact (hence, ‘emission’ and not ‘impact’ is the basis for calculating the monetary values).

The basis for the environmental evaluation in this research is the mode operation. However, the ‘life-cycle’ of transportation activities also includes infrastructure construction; vehicle manufacture; operations, maintenance and support¹⁰⁹; and disposal of vehicles, parts and facilities (EPA, 1999a). Each element imposes an environmental impact and damage that should be considered. To that, the ‘upstream effects’ of fuel processing, storage and distribution needs to be added. Again, considering all these elements is outside the scope of

¹⁰⁷ The way this conflict was resolved is described in section 3.2.

¹⁰⁸ Even the US Environmental Protection Agency (EPA), one of the most authoritative environmental research agencies, states that “unfortunately, quantified estimates of environmental outcomes are often unavailable or uncertain. Also, it is frequently difficult to separate the effects of transportation from other sources. In practice, many outcome indicators are subject to uncertainty or are qualitative in nature” (EPA, 1999a: 6).

¹⁰⁹ These include activities to support travel (such as the application of de-icing chemicals), and facilities to support travel (such as gas stations and airport terminals).

this research and the focus is on the most important/damaging environmental element: transport operation, or the travel element.

The operation of electric HSTs results in virtually zero emission from the train, but the production of the electricity used by the HST certainly results in emission that affects the environment. This represents one of the methodological problems of comparing two different modes. Associating the emissions from the production of electricity with the HST operation was considered a more robust approach than considering zero emission from HST operation. The latter can wrongly lead to assuming that a HST is a 'clean' mode of transport¹¹⁰. It must be acknowledged that emissions related to the production of Kerosene fuel were not considered.

Giving the difficulties in comparing two different modes on the same basis, especially using monetary values, measures of energy consumption are often used instead. Such an indicator will be placed in Figure 11 before the 'emission' stage. Since detailed emission estimates were available, they were preferred and were considered to lead to a sounder analysis¹¹¹.

3.4.2 Comparing the impact of aircraft and HST operation on Local Air Pollution

Air pollution can be defined as a situation where the ambient concentration of gases and chemical substances is altered as a result of human activities, and in this case transport operation. It is considered to be local phenomena since the effects from the emission of a pollutant are usually limited to the area close to where emission occurs, hence **Local Air Pollution (LAP)**. Away from the sources of emission, pollutant concentration is diluted and the ambient concentrations fall to levels that cause no harm. Air pollution affect not only humans but also vegetation, animals and ecosystems in general, and in this case transport operation also has an adverse impact when it occurs away from populated areas.

"The five major air pollutant species which comprise the most significant emissions from commercial jet aircraft are Volatile Organic Compounds [VOC], Carbon Monoxide [CO], Oxides of Nitrogen [NO_x], Particulate [PM₁₀], and Sulphur Dioxide [SO₂]" (EPA, 1999b: 2-1). Emission of these pollutants from aircraft operation needs to be compared with emission of these pollutants from the operation of HST services. The literature does not always distinguish between VOC and Hydrocarbons (HC), and therefore, despite recognising that

¹¹⁰ In the past, electric trains were considered to be a clean mode of transport (e.g. TEST, 1991).

¹¹¹ Energy rates are an indicator for fuel consumed, and do not consider the effect and the result of combustion, which is why 'emission' is considered to be better.

HC and VOC are not the same, they will be treated as the same pollutant in the analysis¹¹². A high level of Ozone (O₃) at ground level is also known to affect human health. Ozone, however, is not emitted during aircraft and HST operation but it is created as a consequence of the emission of other gases from aircraft and HST operation. Since it depends on many different chemical reactions, Ozone creation cannot be quantified accurately, and it is excluded from the analysis. The health and environmental effects associated with the emission of the above pollutants are described in Appendix C.

Pollutants emitted from aircraft at high altitude, hence by definition away from people, are not considered to affect LAP. The standard, set by the ICAO, is to consider aircraft emission at ground level and at a flight level of under 915m (3000ft), which includes a few minutes after take-off and before landing and the time the aircraft is taxiing or idling (but with engines on) on the ground (Archer, 1993; EPA, 1999b). This is known as the Landing Take-Off (LTO) cycle. For HST, the practice is to consider the whole journey since emission of pollutants is at ground level. This, however, does not take account of the fact that pollutants emitted away from populated areas have no affect on human health.

The LTO cycle consists of five different stages in which the engines operate at different power (thrust) for different periods of time. They were considered in order to calculate fuel consumption and based on that, the aircraft emission profile during the LTO. The boundary for the LTO cycle is determined by the height of the 'mixing zone', which is "the layer of the earth's atmosphere where chemical reactions of pollutants can ultimately affect ground level pollutant concentrations" (EPA, 1999b: 2-8). "The height of the mixing zone for a given [airport] location varies significantly by season and time of day" (ibid). The time the aircraft is climbing and descending depends on the height of the mixing zone, and the flight procedure adopted by the pilots. The taxiing and idling time will vary between airports, mainly due to runway layout and congestion levels at each specific airport. The ICAO standard of 915m might be considered to be an upper limit approximation since it was assumed to approximate summertime conditions in which the mixing zone is higher for a given time of day than in the winter (EPA, 1999b). Furthermore, the EPA found that for many areas in the US the mean mixing zone was significantly lower than 915m (ibid).

¹¹² The EPA states that "organic chemicals emitted into the atmosphere are typically described as VOCs (or 'hydrocarbons')" (EPA, 1999b: A-5, my emphasis). The CfIT (2001) compares between HC emission from aircraft, NMVOC (Non-Methane VOC) emission from HST, and VOC emission from surface access (to airports) emissions, and conclude that "CO, NOX and HC emissions from surface access are all significant compared to the emissions from the regional trip by high-speed rail or domestic aircraft" (ibid: 19). Finally, Dings et al (2002b) survey recent monetary estimates of the environmental effects of aviation and treat HC and VOC as the same pollutant.

Table 8: The Landing Take Off cycle

Image removed due to third party copyright

Source: ICAO (2002b).

In terms of total volume of fuel consumed (which might be an indicator to the volume of emission) the length of time of each LTO stage and the engines' thrust are the main determining factors. Table 8 shows that most of the fuel is consumed during the idling and taxiing stage when engine thrust is at 7%. However, the mix of emission from aircraft is not dependent on fuel consumption only, but on the combustion temperature as well. For example, when engine power and combustion temperatures are low output of NO_x is low, but emissions of CO and HC are at their highest. Also, emission of particulates is significant during idling and taxiing when engines operate at a fraction of their optimum efficiency since they are the products of incomplete combustion. However, emissions of SO₂ are directly related to the fuel consumption and do not relate to engine power and combustion temperature (Archer, 1993).

In contrast, rail operation is usually considered as one stage, although at different stages of operations, e.g. accelerating, braking and cruising, the energy consumption differs significantly. Emissions from electric rail operation are regarded as linearly related to energy consumption, and are measured based on the amount of energy consumed and the sources of energy used to generate the electricity. It is usually assumed that electricity for rail services is supplied from the national grid and emissions are calculated based on the average electricity generation mix (CfIT, 2001a).

3.4.2.1 Comparing aircraft and HST impact on local air pollution – empirical analysis

Since emission from (passenger) aircraft and HST is directly related to the capacity (seats) offered (i.e. the size of aircraft and HST), and not so much to the percentage of seats actually occupied by passengers, the preference for seat rather than passenger units (described in section 3.1) is reinforced. Furthermore, the choice of the 'route' as the distance unit is especially justified when comparing the modes' impact on LAP. The practice of presenting aircraft impact on LAP in emission per km units leads to underestimation of LAP since

emission during the LTO cycle is almost independent of route distance¹¹³. In addition, when considering emission throughout the entire flight and not during the LTO cycle only, aircraft affect on LAP is significantly overestimated.

The first basis for comparison between the two options of travel on the case study route was emission per seat supplied on the route. EPA (1999b) data on HC, CO, NO_x, and SO₂ emissions from aircraft during the different stages of the LTO cycle stages was used for the A320-200 and B737-300 aircraft models. This was supplemented with data on PM₁₀ emission given by the CfIT (2001a)¹¹⁴. For the HST, emission data provided by Quinet (1994) specifically for the TGV (based on 1992 study), and data given for the London-Manchester route (CfIT, 2001a) is used. Amongst other things, the difference between the estimates should represent the difference in the mix of energy sources used to generate electricity in France and the UK respectively. Given the time difference at which the studies were carried out, the differences might be attributed to better data and measuring methods available in 2001 compared to 1992.

Emissions occurring during the egress journey from the airport (CDG) to Paris city centre (attributed to the aircraft option of travel) were calculated based on the access-to-airport modal split at CDG (69% use of car, 31% public transport (TCRP, 2000)); and on emission estimates for car (capacity of 4 seats assumed¹¹⁵) and bus (representing public transport modes, capacity of 70 seats assumed). The route distance (CDG-Paris) was assumed to be 24 km (ibid). Including also metro, light rail, and rail services as public transport modes would probably result in lower emissions (mainly due to the higher capacities of these modes), but considering the dominance of the car on these journeys it was unlikely to significantly affect the results.

Because of the different effect each pollutant has on LAP, summing the total emissions across the different gases has not much meaning. Instead, the impact on the environment inflicted by the emission of each pollutant must be considered. Most studies estimate such an

¹¹³ For a 100 and a 1,000 km flight the aircraft must complete the LTO-cycle. However, the longer the flight the more fuel is needed to be carried at take-off and climb stages of the LTO cycle leading to higher fuel consumption and subsequently higher emission for the 1,000 km flight.

¹¹⁴ The study provides surface emission rates (i.e. emission during the LTO) for different domestic routes in the UK, together with the mix of aircraft types operating on the route and their seat capacity. On the London-Leeds route the majority of services (89%) were operated by B737 (the rest of the services were operated by the smaller Fokker 100), therefore emissions of PM₁₀ calculated for this route are used as an estimate for the B737 in this research. The distance between the cities was used to convert emission/km units to emission/LTO-cycle. There was no route in the study where the A320 was the main aircraft in use, and therefore a specific estimate for A320 could not be derived. The sources the CfIT (2001) study use to estimate aircraft emissions of PM₁₀ are not provided. Archer (1993) and EPA (1999b), usually the sources used to calculate aircraft emission, do not have estimates for PM₁₀ emission.

¹¹⁵ In line with using the aircraft and HST seat, and not passenger, capacity.

impact in terms of human rates of morbidity and mortality, but these estimations vary significantly between studies and within studies and are given for different effects (e.g. the effect on mortality, on respiratory hospital admissions, etc. (Maddison et al, 1996)), making them difficult to use in this analysis. Instead, the toxicity factor of each pollutant, used by Quinet (1994), is adopted as the common denominator that allow to sum together the relative impact on LAP caused by each pollutant emitted during the journey, and this yields a meaningful comparison between the modes. Although such an indicator of environmental impact is very useful, no other studies that use this indicator were found. Since this was the only indicator that allows comparison of the impact across all the pollutants measured, it was adopted¹¹⁶.

To evaluate the cost of impact/damage associated with LAP from each option of travel, the most up-to-date estimates for the cost of damage caused by each pollutant were applied to the emission measured from each option of a journey.

Dings et al (2002b) survey the monetary valuation of NO_x, PM₁₀, HC, and SO₂ emission per kilogram emitted, based on damage costs, in recent European literature (the studies used are from either 1999 or 2000). Then they average the estimates across the findings to derive one value for estimation of the cost of damage caused by aircraft emissions during the LTO cycle¹¹⁷. Since there is no possibility to determine which of the studies (or estimates) is better or more robust, using the average across the studies seems the least unfavourable option. This method is also used by Lu and Morrell (2001), but since they base their estimates on older studies (1996-1998) the estimates derived by Dings et al (2002b) were preferred.

The evaluation of LAP from aircraft and HST operation is presented in section 4.3.1.

3.4.3 Comparing the impact of aircraft and HST operation on climate change

The term 'climate change' (also referred to as the greenhouse effect, or global warming) usually refers to the increase in ambient concentration of certain gases, the Greenhouse Gases (GHGs), as a consequence of human activities, which leads to an increase in the earth-temperature and subsequently climate change. The IPCC Second Assessment Report from 1995 states that "increases in greenhouse gas concentrations since pre-industrial times (i.e., since about 1750) have led to a positive radiative forcing of climate, tending to warm the

¹¹⁶ The DfT states that "robust values of the effects of local air quality on health are not available" (DfT, 2003a: 129).

¹¹⁷ All the studies in their survey refer to valuation of ground level effects which makes them robust for use in this research, also for the HST.

surface of the Earth and produce other changes of climate” (IPCC, 1999: 4). Part of the increase in GHG concentrations is directly related to transport operation.

Climate change is a global phenomenon and there is no direct relation between the location of emissions and the location of the effect, although emissions, especially from aircraft, can have a regional effect on climate. However, there is a direct relation between the altitude at which emission occurs and the level of affect on climate change (except for CO₂).

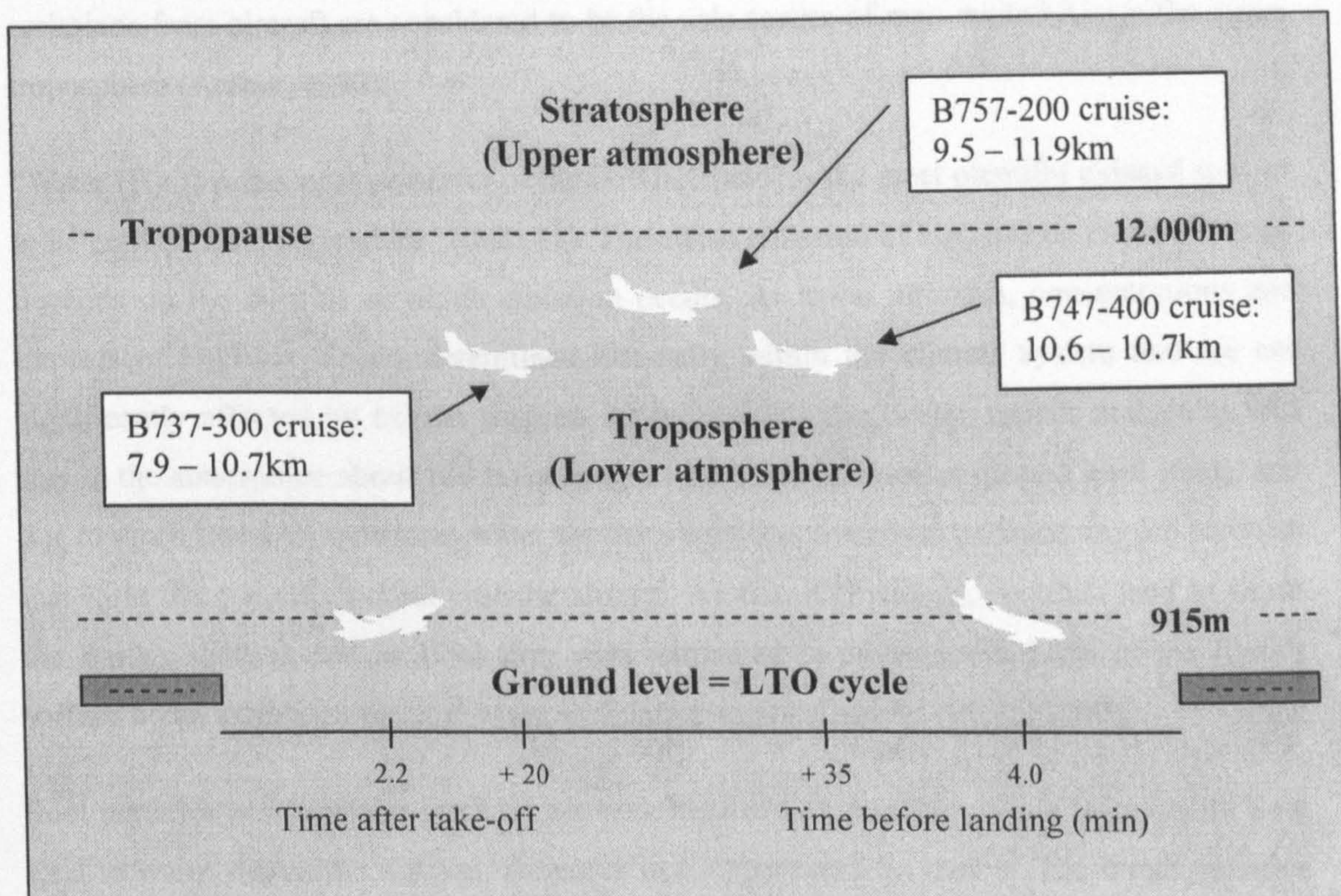
Differences in the elements of the atmosphere at different altitudes mean that emission from aircraft emitted above ground level has a different impact on the environment than aircraft and other modes' emission at ground level. This leads to “emissions from aircraft contributing far more to global warming than the same level of emissions from surface-based sources” (Environmental Audit Committee, 2003: 8). Regarding aircraft operation affect on climate change, the atmosphere can be divided into three parts: ground level, the Troposphere (lower atmosphere), and the Stratosphere (upper atmosphere) (Figure 12). The ground level part of the atmosphere is the one considered for the analysis of LAP (up to 915m). Above that, the troposphere is up to about 12 km at mid latitudes (8 km at the Polar regions and 16 km in the tropics), and beyond that it is the stratosphere (Archer, 1993). Most aircraft cruise at an altitude of between 10 to 12 km, i.e. at the boundary between the Troposphere and the Stratosphere, called the Tropopause. Most (subsonic) aircraft will probably not reach the stratosphere during cruise.

Since different gases affect climate change in different manners and magnitude, measuring the emission of these gases is not enough. However, due to complex chemical reactions in the atmosphere, it is very difficult to evaluate the impact of emission on climate change. In the case of CO₂ and H₂O, this is less complicated since CO₂ and H₂O emission increases or decreases in direct relation to the amount of fuel consumed, and regardless of where and when emission occurs. Further complexity is added by the fact that the emission of the same gas can increase and decrease climate change depending on where emission occurs.

The main GHGs emitted from the operation of aircraft and HST are Carbon Dioxide (CO₂), Nitrogen Oxides (NO_x), Water Vapour (H₂O), and Sulphate and soot aerosols. However, despite the growing recognition that emissions from flying aircraft have greater impact on climate change than emissions at ground level, “emissions above 915 meters are not measured, factored, nor accounted for in an aircraft pollution profile” (ibid: 45)¹¹⁸.

¹¹⁸ However, “The International Civil Aviation Organisation has begun work to assess the need for standards for aircraft emissions at cruise altitude to complement existing LTO standards for NO_x and other emissions” (IPCC, 1999: 11).

Figure 12: The atmosphere layers and aircraft's flight and cruise altitude



CO₂ is the main GHG and it results from the combustion of fossil fuel. Since CO₂ is a natural constituent of air it is not strictly a pollutant and excess amounts of the gas have no detrimental effect on personal health (Button, 1993). However, increased levels of CO₂ in the atmosphere lead to global climate change. CO₂ is chemically inert; its concentration is not affected by chemical reaction nor is the tropospheric chemistry affected by CO₂. What goes into the atmosphere stays unchanged there for a long time (50-200 years) (Archer, 1993). It is this property of CO₂ which makes it the most important GHG.

Nitrogen and Oxygen can combine to produce a variety of compounds, one of which is Nitrous oxide (N₂O). The environmental effect of N₂O is mainly on climate change, while the environmental effect of other compounds of NO_x is mainly on LAP. Emissions of NO_x have two major impacts in relation to climate change: they create Ozone and deplete Methane. Since both are GHGs, NO_x emissions affect climate change in opposite ways. It causes warming by the creation of Ozone and cooling by the depletion of Methane but the effects do not cancel each other. “Within the lower atmosphere [NO_x emissions] contribute significantly to...global warming” (Archer, 1993: 62). During short haul flights, aircraft are considered to remain within the lower atmosphere, hence NO_x emissions from such flights are considered to lead to an increase in Ozone and thus to an increase in global warming. In addition, aircraft emissions of NO_x are more effective in producing ozone in the upper

troposphere than an equivalent amount of emission at the surface (IPCC, 1999)¹¹⁹. NO_x emissions from aircraft are considered to be the sole source of man-made NO_x in the upper troposphere (Archer, 1993).

“Water [H₂O] is the most powerful of the GHGs...[and] is the most plentiful exhaust species to be emitted from jet engines” (ibid: 71). The effect emission of H₂O has on climate change depends on the altitude at which emission occurs. At lower altitudes, concentrations and impacts of H₂O are largely determined internally within the climate system and are not significantly affected by human sources. At higher altitudes, water vapour molecules will stay in the atmosphere about 100 times longer than when released at ground level (ibid), and due to much lower temperatures water vapour sometimes freezes to produce tiny ice particles that form the contrails behind cruising aircraft. As thin high clouds, contrails tend to warm the Earth's surface, and in 1992 they were estimated to cover about 0.1% of the Earth's surface on an annually averaged basis, with larger regional values (IPCC, 1999).

Soot particles and Sulphate particles are both regarded as aerosols. While increases in Soot tend to warm the earth's surface, increases in Sulphate tend to cool it. The direct radiative forcing of Sulphate and soot aerosols from aircraft is small compared to those of other aircraft emissions, and the aerosol mass concentrations, in 1992, resulting from aircraft are small relative to those caused by surface sources (IPCC, 1999).

3.4.3.1 Comparing aircraft and HST impact on climate change – empirical analysis

The methodology used to evaluate LAP was followed in the evaluation of climate change, i.e. comparing between the modes in terms of (GHG) emission, impact, and cost of damage from climate change. Not all of the GHG mentioned above are included in the analysis, mainly due to the different characteristics of a short haul flight compared with a long haul flight in terms of time spent at cruising altitude. For reasons explained below, emissions of Sulphate and Soot aerosols and H₂O were excluded from the analysis.

The main reason for excluding Sulphate and Soot aerosol emission was lack of quantitative data on their contribution to climate change. Since the impact on climate change from aircraft emission of Sulphate and Soot aerosols is considered small (see above), it does not significantly reduce the robustness of the analysis.

¹¹⁹ This was also reported by Archer (1993) quoting different sources.

At lower altitudes, concentrations and impacts of H₂O are largely determined internally within the climate system and are not significantly affected by human sources (Archer, 1993), as noted above. Although there is no agreement at which altitude the effect of H₂O emission on climate change is substantial, there is enough evidence to conclude that during a short haul flight of around 70 minutes (the common London-Paris advertised flight time), H₂O emission from aircraft will not occur at altitudes where H₂O has a significant impact on climate change. Therefore, although data was available to calculate H₂O emission from aircraft operation, this gas was also excluded from the analysis.

Archer (ibid) considers lower altitudes, where the effect of H₂O emission on climate change is negligible, to be up to 9 km and higher altitudes to be 9-13 km. The distinction made by the IPCC (1999) is that water vapour emissions in the troposphere, where most subsonic aircraft water vapour emissions are released, will be removed by precipitation within 1 to 2 weeks. The A320 service ceiling (maximum cruise altitude) is 12.2 km (Endres, 2001), and the B737 cruise at approximately 8-10 km (Archer, 1993). Assuming a flight time of 70 minutes between Heathrow and CDG that includes, on average, a LTO cycle of 33 minutes leaves only 37 minutes for climb, cruise, and descent. On such a short flight, aircraft are not likely to get above 25,000 ft (~8.3 km), and in this case cruise time will be virtually zero¹²⁰. In most cases, the cruise altitude is lower, and is limited to 22,000 ft (~7.3 km) by ATC restrictions in order to reduce controllers' workload (Alder, 2004)¹²¹. It can be concluded that the flight on the case study route is not likely to reach the altitude where H₂O emission affects climate change. The same argument is the basis to assume that aircraft affect on climate change through the formation of contrails is unlikely to occur on a short haul flight. The IPCC (1999) states that the upper troposphere is where contrails are formed preferentially.

For the reasons stated above, the analysis of the impact of aircraft and HST operation on climate change considered emission of CO₂ and NO_x gases only. To evaluate aircraft operation impact on climate change, the whole flight, from the moment the engines are turned on until they are turned off, must be considered. Therefore, emissions during the LTO cycle must be complemented with emissions from the rest of the flight, which were divided between emissions during climb and descent (with the appropriate engine setting and emission estimates used to evaluate LAP). CO₂ emissions are estimated based on fuel consumption and assuming emission rate of 3.15kg CO₂ for every kg of Kerosene fuel

¹²⁰ This means that after the LTO cycle (at 3,000 ft, or 915m) the aircraft will climb until required to start its descent.

¹²¹ This information is based on an email exchange with Mr. Alder, chairman of the British Air Line Pilot Association (BALPA) Flight Safety Group.

consumed (DfT and HM Treasury, 2003)¹²². Fuel consumption was calculated based on estimates from the ICAO engine exhaust emissions data bank for the specific engines used by the B737 and the A320 for the different LTO cycle modes (ICAO, 2002b).

Converting NOx emissions at ground level and at higher altitudes to CO₂ equivalent units allow the aircraft and the HST journeys to be compared taking into account both gases and their impact on climate change relative to the altitude at which emission occurs. Thus, CO₂ equivalent units are used as an indicator for the impact on climate change. Finally, monetary values were assigned to the level of emission to measure the cost of impact on climate change from aircraft and HST journey between Heathrow and Paris. The evaluation of the impact of aircraft and HST operation on climate change is presented in section 4.3.2.

3.4.4 Comparing the impact of aircraft and HST operation on noise pollution

Noise is defined as unwanted sound (DEFRA, 2001), and with the increase in noise silence is becoming an increasingly scarce commodity. Hence, by definition noise is subjective; noise to one person can be music to another. However, in the case of sound generated from the operation of transport vehicles, there is probably consensus that it is noise. The subjectivity appears in the level of noise considered to be annoying. In part due to the subjectivity aspect of noise, “the effects of transport noise are not very well understood...[and] there is no fully satisfactory measurement of noise and the nuisance it causes” (Quinet, 1994: 8). Despite much research and improved techniques to measure and evaluate noise from transport operation, Quinet’s conclusion still holds today, but probably to a lesser extent.

There is no dispute that above certain level noise can cause annoyance to people and result in other consequences. There is, however, less agreement on the effect of noise on human health, mainly because it is hard to prove such a relationship. The DEFRA states that “it is likely that for the foreseeable future it will remain extremely difficult to establish casual relationships between noise and health related problems” (DEFRA, 2001: 33). The adverse effects of noise can be assessed in two ways. One is in an objective way, i.e. in terms of physical and mental states of clinical significance; the other is in a subjective way, i.e. in terms of wellbeing, quality of life and perceived state of health (ibid). Any effect of noise on human wellbeing can influence both the objective and subjective effects of noise. The objective effects are more difficult to prove and quantify, but the subjective ones, by definition, are subject to bias and are less clear. A World Health Organisation report from

¹²² This was the most up-to-date estimate found. Archer (1993) assumes a ratio of 2.95kg CO₂ for every kg of fuel consumed.

1993 found that “noise gave rise to a large number of health problems” (Whitelegg et al, 2001: 11). A review of the literature, made in 2000, led to a conclusion that “exposure to noise constitute a health risk” (Bronzaft, 2003: 38). However, a study cited by the DEFRA concluded that “the literature confirms that there are a number of potential effects of noise on health, although the evidence in support of actual health effects other than those based on reported bother or annoyance and on some indicators of sleep disturbance is quite weak” (DEFRA, 2001: 33). Despite the disagreements on the effects of noise, there is agreement that noise generated from transport operation constitutes an environmental problem and therefore it needs to be considered in this research.

Noise from railway operations has been part of everyday background noise since the 19th century. The wheel/rail rolling contact noise is the main source of railway noise for electricity powered trains and, in many cases, for diesel trains. The level of noise generated by this mechanism depends on the speed of the train and on the smoothness of the wheels and railhead. Wheels that are comparatively smooth, as with disc-braked trains, are particularly sensitive to corrugation (a periodic wear pattern). Severe corrugation can increase rolling noise by as much as 20 dB, a subjective four-fold increase in loudness (CfIT, 2001a). Sliding contact between the wheel flange and the rail can cause high levels of tonal noise or wheel squeal and can damage the wheels, potentially leading to more noise. This feature typically occurs in areas where there are relatively tight bends in the track, badly maintained stock or where adhesion is reduced (DEFRA, 2001). Another source of noise from train operation is the train braking system. Two types are usually considered: tread brakes and disc brakes. The latter is considered more advanced and less noisy. In the case of HST, another braking system is used, rheostatic braking. “Since rheostatic braking produces a substantial amount of electric current which in turn generates heat, fans must be used to dissipate the excess heat safely. The fan used can be significant noise sources for some types of operation which need to be taken into account” (Department of Transport, 1996: 1). So, although electric trains, including HSTs, do not have engines that generate noise, they have a fan that is a source of noise. The fan is probably the dominant source of noise when the trains run at relatively low speeds or when idle at stations (for other trains, the engine is the dominant source of noise), and at speeds between 50 and 300 kph, rolling noise is the most important noise source. Only at speeds above 300 kph is aerodynamic the main source of noise from running trains. Thus, even for HSTs, rolling noise is probably the dominant noise source (Brons et al, 2003).

The speeds HSTs operate at require special track, high level of maintenance and modern trains. This means that a HST railway, in general, will have no tight bends or curves,

continuously welded rail (CWR), and trains which are equipped with disc brakes. This probably leads to less noise generated from HST operation in comparison with conventional trains when the two types of train travel at the same speed.

With regard to noise from aircraft, the dominant source of jet aircraft noise, throughout the take-off and climb and through most of the approach, is the engines. Airframe noise may be significant in the final approach phase (DEFRA, 2001). Janić (1999) defines two sources of noise from any aircraft engine: machinery and primary jet noise. Machinery noise is noise produced as a result of rotating engine parts, such as the fan, compressor and turbine; and primary jet noise is generated by the mixing of high speed gas exhausting from the engine with the surrounding air. The main source of noise during the take-off is the primary jet noise, while machinery noise appears as the major source during landing.

Improvements in aircraft noise come mainly from engine modification (the introduction of high by-pass combustion technology to aircraft engines (ibid)); improved climb performance (rapidly increasing the distance between the aircraft and the population under the flight path); restrictions on the use of reverse thrust (DEFRA, 2001); and from replacing 'noisy' aircraft with quieter ones¹²³. Still, it is assumed that "noise could be reduced for only about 0.3 percent per year during the next five years" (Janić, 1999: 172), and the forecasted increase in aircraft movements (see section 2.1.4) makes this improvement almost insignificant.

Compared with road and aircraft noise, rail noise is considered to be less disturbing¹²⁴. This is usually referred to as the 'rail bonus'. This bonus is estimated by the CfIT (2001) at 10 dB. Navrud (2002) recommends a rail bonus of 5 dB. Since the way people hear or perceive noise is more important, in terms of measuring noise pollution from transport operation, than the actual sound produced, the existence of a railway bonus must be acknowledged.

¹²³ The rapid growth of aviation led the ICAO to introduce noise standards within volume 1 of Annex 16 to the convention on International Civil Aviation (the Chicago convention) with the specific purpose of controlling noise at source. Standards were developed first for sub-sonic jet aircraft, the so-called Chapter 2 types (the reference is to the relevant chapter within volume 1 of Annex 16). Subsequently, tougher standards (Chapter 3) were introduced in 1977 to apply to newer aircraft, all subsonic jets and heavy propeller driven, those of 8000 kg maximum take-off mass or more. In January 2001, ICAO's Committee on Aviation Environmental Protection (CAEP) agreed recommendations for a new noise standard for jet aircraft, cumulatively 10 dB lower than the Chapter 3 standards. In June 2001, ICAO council adopted the new, chapter 4, standard that will be in effect starting 1 January 2006 (ICAO, 2002a). Chapter 2 aircraft were withdrawn from service in the UK from April 2002 (DfT, 2003a).

¹²⁴ This might explain why "research on noise annoyance caused by railroad traffic is relatively underdeveloped" (Brons et al, 2003: 169). Yet, it seems recently this dearth has been reduced (e.g. Brons et al, 2003; Nijland et al, 2003; Pronello, 2003).

The increased awareness to noise pollution, and especially from transport operation, lead to increasing research on the subject and improved techniques for measuring noise pollution and estimating the economic value of noise pollution. The state-of-the-art of the economic valuation of noise is provided by a study for the EC (Navrud, 2002)¹²⁵. Appendix D provides discussion on measurements and standards of noise.

3.4.4.1 Comparing aircraft and HST impact on noise pollution – empirical analysis

The methodology used in the analysis of LAP and climate change can be used here following the steps outlined in Figure 11. This means that the first step is to measure the emission of noise or the amount of noise created by each mode on a specific and defined route. However, as noted above, the level of noise generated (noise at source) is of less concern than the level of noise heard at a specific location (usually a residential building), the former commonly referred to as **emission** and the latter as **immission** of noise (Brons et al, 2003). Second, the impact of the noise needs to be evaluated, for example by estimating how many people are exposed to certain levels of noise from HST and aircraft operation, a common practice especially with regard to aircraft operation around airports. Finally, monetary values need to be assigned to the impact in order to measure the cost of damage or annoyance caused on the same basis that other environmental effects were measured.

Numerous factors influence the noise heard compared to the noise produced, and these can be categorised into factors influencing the spread (movement) of noise (e.g. wind, natural and man-made barriers, type of surface, etc.), and factors affecting the level of noise heard (distance from noise source, background noise, duration of noise, etc.). To enable the measurement of noise from different sources, those factors must be identical. This can never be the case when two different modes are considered; it is usually never the case even when measurements are made within the same mode. However, these can be considered as ‘ambient conditions’, which are usually not accounted for due to the extra complexity involved, or can be assumed at a certain level (e.g. often the noise level referred to is the ‘free field’ level, which means “in the open and away from acoustically reflective surfaces, and not within properties” (CfIT, 2001a: 29)).

Even when ignoring the ambient conditions which affect the noise heard, many obstacles to evaluating the benefits of noise reduction in this research remain. To begin with, “harmonised indicators for the noise from railways and aircraft are currently not available”

¹²⁵ The study also provides discussion on the theoretical basis of monetizing noise pollution and valuation techniques.

(ibid: 28)¹²⁶. Nevertheless, there is no reason why methodologies adopted to evaluate the impact of noise from aircraft operation could not be used for the railway mode as well. In particular, the study by Pearce and Pearce (2000), which derives the monetary value of noise generated by a single landing and take-off of a specific aircraft type at Heathrow, provides a methodology that can be repeated for a railway line¹²⁷.

The relatively dearth of research on railway noise means that, in addition to the methodological problems of comparing between the modes, there is limited data on noise impact from railway, and even more so on HST operation. What is available and to what degree this could be used to evaluate the benefits of reduced noise pollution from airline and railway integration is discussed in section 4.3.3.

3.4.5 Conclusions

The evaluation of environmental benefits from airline and railway integration is central in this research for two reasons. First, the literature suggests these are expected to be one of the main benefits from aircraft and HST substitution. Second, research which carried out a thorough analysis that showed the advantage of the HST compared to the aircraft was not found. When such analysis was found, for example CfIT (2001), only the modes' emission was considered. Most studies, however, simply point out that the HST is an environmentally better mode than aircraft.

Analysis of the environmental benefits from airline and railway integration was the most complicated and challenging part of the empirical analysis in this research. This is because transport operation impact on the environment is not yet fully understood, especially the impact of aircraft operation. The methodology adopted to evaluate environmental benefits in this research is a practical approach to the methodology described in Figure 11. It was based on comparing the modes on three levels: emission, impact of emission, and the cost of damage caused by emission. In accordance with the methodology described in 3.1, the comparison was in seat per route units (e.g. emission is measured in gram per seat per route).

¹²⁶ Similar statement is made by Janić (2003b).

¹²⁷ Lu and Morrell (2001) describe similar methodology and derive similar values.

4. Evaluating benefits from operating airline and railway integration

This section presents the empirical analysis of airline and railway integration on the case study route, Heathrow airport to Paris city centre. Based on the methodology described in section 3, the benefits from operating airline and railway integration were evaluated.

First, the benefits to airlines (section 4.1), passengers (section 4.2), and society (section 4.3) were evaluated separately and then summed together (section 4.4) in order to derive the net benefits from the operation of airline and railway integration. In addition, the potential to alleviate congestion, by freeing runway and ATC capacity, was evaluated in order to estimate the contribution of mode substitution to this problem and to allow assessment of the potential for benefits at the airport level.

The financial analysis (FA) to evaluate airline benefits was, from a methodological perspective, a relatively straightforward exercise, the quality of which depended mainly on the quality of data available. Therefore, the presentation of the FA requires a relatively short section. The evaluation of benefits to passengers was more complex, especially the application of the VOT theory to the empirical analysis in this research. Therefore, more space is devoted to describing the evaluation of benefits to passengers. The environmental analysis was considered to be the most complex and where significant contribution to the literature was expected, both from the empirical findings and the methodology used. This section, therefore, required a detailed description of the evaluation process, the results, and separation, to begin with, between Local Air Pollution (LAP), climate change, and noise analyses.

4.1 Evaluating operating cost benefits to airlines from airline and railway integration

This section considers one element of airline and railway integration, the potential for financial benefits to airlines from the operation of airline and railway integration. The aim is to identify and quantify these benefits.

The strongest driving force for airline and railway integration is the potential gains to airlines from such policy. In a deregulated aviation industry, it is up to the airlines to determine if such a change in airline operations should take place, and the airlines' decision is, first of all, a financial decision based on the potential for financial benefits. Financial benefits from airline and railway integration depend on a variety of aspects but at the core on whether the aircraft operating costs (OCs) are higher than the HST OCs. This is evaluated below.

Because it is mainly the airline's decision if to adopt mode substitution, the airline, rather than the TOC, is the main concern of the evaluation, and therefore the analysis is performed from the airline's point of view. This does not mean the TOC is not likely to benefit from airline and railway integration it does, and these benefits are discussed in section 5. The approach is also justified by emphasizing that, if the analysis shows that the HST OCs are lower than the aircraft OCs, it can be expected that airlines would substitute the aircraft with the HST but, if the aircraft OCs prove to be lower than the HST OCs, then it is unlikely that the TOC would substitute the HST with the aircraft.

The evaluation begins with analysing the aircraft OCs and then the HST OCs. Following that the modes' OCs are compared and the case for mode substitution under airline and railway integration, from the airlines' point of view, is discussed.

4.1.1 Aircraft operating costs

The costs of operating a flight can be divided between the actual OCs of the aircraft, and the different charges levied on the use of infrastructure and navigation services. Data for the OCs of different types of aircraft is regularly published in the Air Transport World magazine, and this was the best available data to estimate the costs of a flight. The data provided is the direct OCs¹²⁸ (Table 9). The costs are for an aircraft block hour¹²⁹ based on

¹²⁸ The cost categories include: crew cost; fuel & oil; direct maintenance, labour & material; maintenance-outside & overhead; and possession, insurance & other.

the 2001 fleets. The differences between the aircraft are probably due to the differences in size, stage length, and production year. For the A320 and the B737 specifically, the differences probably suggest an economy of scale is achieved when increasing the aircraft size and when operating longer routes (Williams, 2001). Most of the OCs are attributed to fuel-and-oil and crew components.

4.1.2 HSI

Table 9: Aircraft operating costs and performance (2001)

Aircraft	A320	B737-300
Typical seat capacity ¹	150	128
Maximum Take-Off Weight (kg) ¹	77,000	56,470
Block Hours (thousands) ²	879	2,275
Average stage length (km) ²	1744	957
Fuel & oil cost (€/block hour, (% of OCs)) ²	633 (26%)	666 (28%)
Crew cost (€/block hour, (% of OCs)) ²	699 (29%)	532 (22%)
Direct OCs (€/block hour) ²	2448	2378
Direct OCs per seat (€/block hour)	16.3	18.6

Source: ¹ Endres (2001) ² Air Transport World (2002a; 2002b)

Based on 70 minutes scheduled flight time¹³⁰, different charges imposed on each flight were added to arrive at the total OCs for a flight on the case study route (Table 10). These charges include: airport landing charge, airport parking charge¹³¹, and two charges for Air Traffic Control (ATC) services¹³². Appendix E details the different charges and how they were calculated for the case study route. At international airports, there are also charges levied on passengers using the airport. Since such charges are not part of the costs directly borne by the airlines, they were not included in the analysis.

Table 10: Direct operating costs of a flight from Heathrow to CDG (Euro)

Aircraft	A320	B737-300
Typical seat capacity	150	128
Operating costs	2,856	2,774
Landing charges	453	368
Aeronautical charges	90	68
Parking charges (45 minutes)	563	457
Direct OCs:	3,962	3,667
Direct OCs per seat	26.41	28.65
Direct OCs per seat-km	0.069	0.075

¹²⁹ Block hour is defined as the time for each flight stage or sector, measured from when the aircraft leaves the airport gate or stand to when it arrives on the gate or stand at the destination airport (Doganis, 2002a).

¹³⁰ A good estimate for average block time on the case study route, especially if accounting for possible delays.

¹³¹ The turnaround time assumed was 45 minutes.

¹³² En-route charge which is paid for flying in the upper air-space, and Air Navigation charge which is for ATC services from the point the aircraft leaves the airport until it reaches the upper air-space, or vice versa.

An A320 flight between Heathrow and CDG costs almost €4,000, and this translates into €26.41 per seat or €0.069 per seat-km. Most of the costs (72%) are OCs per se, and the remaining (28%) are different charges levied on the flight. Per seat and per seat-km, the A320 is more cost efficient to operate on the route than the B737, by about 8% (Table 10).

4.1.2 HST operating costs

A profit and loss statement for the HST services of a TOC was used to evaluate the costs of operating HST services¹³³. The data available was sufficiently detailed to allow the recognition and exclusion from the analysis of cost components that are unique to this specific company, and to differentiate between direct and indirect cost components¹³⁴. Table 11 describes some characteristics of the TOC's HST services, including the load factor (LF) of 47%¹³⁵, and the average journey distance of 411km.

Table 11: Forecast for the rail company's HST services for 2002

Number of passengers (millions) ¹	6.3
Number of train journeys (thousands) ¹	17.5
Number of train kilometres (millions) ¹	7.2
Average number of passengers per train journey	360
Number of seats supplied (journeys x 766 seats, millions)	13.4
Load Factor (assuming 766 seats/train)	47%
Average journey distance (km)	411

Source: ¹ Data from TOC.

Based on Table 11 and the profit and loss statement, the OCs can be deduced for the rail company. For an airline that considers replacing aircraft with HST on short haul services, the costs of customer service, catering, and marketing are not relevant since the airline is assumed to use its own resources for that. In addition, these costs are already incurred by the airline to cater for aircraft passengers, and they would not change, it is assumed, if an airline decides to use trains instead of planes. Thus, considering the TOC's indirect OCs as part of an airline's OCs would amount to double counting. The TOC, HST service, direct OCs

¹³³ The data available is a forecast of the profit and loss statement for the year 2002. For reasons of commercial confidentiality, the company's name cannot be revealed. Reports published by the company in 2003 show that actual passengers carried in 2002 were about 5% above the forecast, suggesting the forecast was relatively reliable.

¹³⁴ Retail costs, customer service, marketing and advertising, catering, overheads, and depreciation (on investments not related to the track or rolling stock) items were classified as indirect costs.

¹³⁵ To arrive at the LF, it was assumed that the TOC operates trains with 766 seats (the capacity of the trains operating between London and Paris).

amount to over €310 million, which translates into €23.25 per seat, or €0.057 per seat-km after accounting for the level of HST services forecast by the company (Table 12)¹³⁶.

Table 12: OCs of HST services forecasted for 2002 (Euro)

	HST
Total OCs (millions)	311.9
Direct OCs per km	43.61
Direct OCs per seat	23.25
Direct OCs per seat-km	0.057

Using OCs per seat-km of €0.057, a route distance of 525km¹³⁷ for the HST line Heathrow to Paris Gare-du-Nord HST station, and a train capacity of 766 seats, the direct OCs on the case study route amount to €22.9 thousand per journey, or €29.89 per seat (Table 13).

Table 13: Direct OCs of a HST service on the case study route (Euro)

	HST
Direct OCs (thousands)	22.9
Direct OCs per seat	29.89
Direct OCs per seat-km	0.057

In order to evaluate the potential OC savings to airlines from airline and railway integration, the direct OCs of a flight should be compared with the direct OCs of a HST journey on the case study route. This is described next.

4.1.3 Comparing the costs of operating HST and aircraft services between Heathrow and Paris

To account for differences in vehicle capacities and different route distances, it is necessary to compare modes using seat-km units. Such comparison reveals that it is cheaper to operate HST services than aircraft services by about 17% (Table 14). This is a clear indication that airlines could benefit from OC savings by substituting aircraft with HSTs and from airline and railway integration. However, for airlines considering airline and railway integration on the case study route, the route distance for the aircraft and the HST is fixed¹³⁸, and therefore comparison in seat units, taking into account the route distance (usually longer for rail), is more appropriate. Taking into consideration the distance each mode has to cover on the route (aircraft: 383 km¹³⁹, HST: 525 km), the HST becomes more costly to operate than the aircraft

¹³⁶ Including the indirect OCs would have led to €48.57 per seat or €0.093 Euro per seat-km. The direct OCs amount to about 62% of the total OCs.

¹³⁷ See section 3.1.2.

¹³⁸ Aircraft must follow ATC routes and would normally not deviate from a specific route.

¹³⁹ The great circle distance between Heathrow and CDG is 348 km plus 10%, yields 382.8 km.

by about 13% per seat on the route (Table 14). As a result, airlines adopting airline and railway integration on the route would clearly incur OC losses. The results were sensitive to the model of aircraft assumed. When using the B737, airline losses from mode substitution increase.

Table 14: Aircraft and HST OCs on the Heathrow to Paris route (Euro)

	Aircraft (A320)	Aircraft (B737)	HST
Direct OCs (thousands)	4.0	3.7	22.9
Direct OCs per seat	26.41	28.65	29.89
Direct OCs per seat-km	0.069	0.075	0.057

Table 15: A320 OCs on the Heathrow - CDG route under different assumptions (Euro)

Assumptions on	Route distance (435km) ¹	Journey time (80 min.) ²	Delays (93 min.) ³	Low cost airline (lower OCs) ⁴
Direct OCs per seat	26.69	29.13	32.67	21.65
Direct OCs per seat-km	0.061	0.076	0.085	0.057

¹ 25% increase in the route distance to 435 km.

² 10 minutes increase in the journey time to 80 minutes.

³ 23 minutes flight delay (with engines on) increases journey time to 93 minutes.

⁴ Assuming 25% lower aircraft OCs, no change in other charges.

The data available to calculate the HST OCs, considered ‘1st best’, meant that the OCs depend on the route distance only, and this is fixed for the case study route. The nature of the available data for the aircraft OCs, however, meant that assumptions were required on route distance and flying time. Route distance influences the OCs through the En-route charges. From the base case, of 10% increase to the great circle distance between the airports (348km), an increase of 25% is assumed, and this leads to a relatively minor impact on the OCs (Table 15)¹⁴⁰. Changes to the flying time have a more significant affect on the OCs because they are the basis for calculating the aircraft OCs per se¹⁴¹ on the route. Increasing the flying time to 80 minutes, almost a 15% increase, increases the OCs per seat and the OCs per seat-km by more than 10% to €29.13 and €0.076 respectively (Table 15). The OCs are almost insensitive to increases in turnaround time, which influences the parking charges. Aircraft OCs are also sensitive to delays, which effectively increase the flight time and hence the OCs through increases in the flight block time (and parking charges if the delay occurs while the aircraft is still at the gate, but this effect was found to be insignificant). The increase in OCs as a result of delays occurring while the aircraft is flying or in operation is significant and amounts to €40.8 per minute of delay (or €0.27 per minute per seat)¹⁴². The

¹⁴⁰ The reason is that the En-route charge is a relatively small cost item. Increasing the route distance increases the route OCs per seat but, because those costs are divided by higher distance, the OCs per seat-km decreases.

¹⁴¹ As opposed to the flight OCs or the total OCs.

¹⁴² While this is a significant increase, its affect on the rest of the airline’s network of services is much more substantial. BA estimates that “every minute one of its Boeing 747s is stacked, it cost them

latest CODA (2004) data shows that, on the case study route 18.3% of the flights were delayed, on average, for 23 minutes¹⁴³. Such a delay, assuming it occurs when the engines are on, would increase the OCs per seat and per seat-km to €32.67 and €0.085 respectively.

The above analysis shows that the results are not sensitive to aircraft flight distance but are sensitive to the assumed flight time or level of delays. Assuming that HST services are not affected by changes in travel times, or by delays, than the aircraft becomes more expensive to operate if the flight time increases by over 13 minutes. Delay data for the case study route suggest this is often the case. Delays to HST services are likely to affect the OCs only marginally. The main reason is that delays will usually occur while the train is not in motion. In addition, cost of electricity is often part of the access charges and therefore is fixed in relation to travel time.

One of the results of the ATI deregulation is the rise of the 'low cost' airlines. These airlines, such as Southwest in the US and EasyJet and Ryanair in Europe, achieve lower OCs than other airlines¹⁴⁴. "Southwest's great achievement has been to operate at cost levels which are 25-40 per cent below those of its major competitors" (Doganis, 2001: 130). Assuming 25% lower OCs for the A320¹⁴⁵ reduces the aircraft OCs per seat-km to the HST's level of OCs, and increases airlines' losses from airline and railway integration on the case study route (Table 15).

Table 16: Aircraft and HST OCs on the Heathrow to Paris route assuming different charges (Euro)

	HST OCs		Aircraft OCs (A320)					
	Base	Impact charge ⁵	Base	Peak charge ¹	Env. charge ²	Carbon charge ³	Kero. charge ⁴	Impact charge ⁵
OCs per seat	29.89	30.70	26.41	27.29	27.32	29.70	30.53	29.39
OCs per seat-km	0.057	0.058	0.069	0.071	0.071	0.078	0.080	0.077

¹ Peak charging: assuming peak-time landing and parking charges.

² Environmental charge: assuming 30% increase in landing charges due to emission charges.

³ Environmental charge: assuming Carbon tax of £70 (€105) per ton of Carbon emission.

⁴ Environmental charge: assuming Kerosene tax of €245 per 1000 litres.

⁵ Environmental charge: assuming the average cost estimate calculated in this research (section 4.3).

\$1,500" (Button et al, 1998: 82). Using the model and data available in this research shows that one minute delay in flight for a B747 results in an OCs increase of €131 for that flight.

¹⁴³ In 2000, 2001, and 2002, 33.7%, 25.2%, and 20.8% of the flights between Heathrow and CDG were delayed, on average, for 32.4, 25.8, and 23.0 minutes respectively (CODA, 2001; 2002; 2003). See also Appendix A.

¹⁴⁴ See Doganis, 2001.

¹⁴⁵ It is acknowledged that part of the reduction in low cost airline OCs is attributed to operating from secondary airports, where landing and parking charges are lower. This will not be achieved by low-cost airlines operating on the Heathrow-CDG route. Thus, 25% lower OCs per block hour, and no change in charges seems a reasonable assumption for the sensitivity test.

Due to lack of capacity and the resulting congestion and delays, some airports impose higher charges at peak periods. At Heathrow, such charges are imposed for landing and parking between 07:00-09:59 and 17:00-18:59 during 1 April to 31 October (BAA, 2001). Adding such charges leads to an increase in the aircraft OCs of around 3% (Table 16), probably not enough to reduce congestion at peak periods, and not enough to justify mode substitution on the route.

Concern regarding transport operation impact on the environment, together with the 'polluter pays' principle, leads to suggestions to impose charges on transport services to account for the environmental impact they impose on society. However, specific environmental charges are usually discussed with regard to the ATI, and not the rail industry. At many airports, for example at Heathrow, CDG and Schiphol, there are at present noise related airport charges (Dennis and Graham, 2001), but such charges would not apply to the A320 and not to a flight that is not operated at night¹⁴⁶. At the Swedish airports, there is at present a charge for air pollution caused by aircraft that relates to the amount of emission emitted during the LTO cycle. For the most polluting aircraft, this leads to a 30% increase in the landing charges (ibid). Applying a 30% increase to the landing charges at CDG and Heathrow (although the A320 is not in the category of the most polluting aircraft) results in an increase of the total OCs by about 3%. There are other environmental charges which are currently under examination. One of them is a Carbon tax. In the UK a value of £70 (€105) per tonne is usually considered (DfT and HM Treasury, 2003). Imposing such a tax on a flight from Heathrow to CDG¹⁴⁷ results in OCs of €29.70 per seat, or €0.078 per seat-km. Another environmental tax suggested is a Kerosene tax of €245 per 1,000 litres of fuel, which is proposed by the EU (CEC, 1999). Adding Kerosene tax to the aircraft OCs based on the A320 fuel consumption on the Heathrow-CDG flight¹⁴⁸ increases the OCs per seat and the OCs per seat-km to €30.53 and €0.080 respectively, about a 16% increase. If a Kerosene charge is imposed on flights then, on the case study route, airline and railway integration becomes beneficial to the airlines, but yields just 2% reduction in OCs per seat. A Carbon tax on flights would not make mode substitution beneficial to airlines (Table 16).

In theory, the most appropriate way for setting environmental charges is to measure the specific environmental burden imposed by each journey. For the case study route, this

¹⁴⁶ The last Heathrow to CDG flight departs at 20:45 (BAA, 2003a).

¹⁴⁷ Following DfT and HM Treasury (2003) methodology of: 1 tonne of fuel = 3.15 tonnes of CO₂, CO₂ emission is scaled up by 2.7 to take account of all emissions, and 3.67 tonnes of CO₂ = 1 tonne carbon. Fuel consumption on the route was calculated to measure aircraft CO₂ emission (section 4.3.2).

¹⁴⁸ Amounts to 2,061 kg, based on ICAO's engine exhaust emission data bank (ICAO, 2002b). 1kg = 1.246 litre. This is also used as the basis to measure aircraft CO₂ emission (section 4.3.2).

burden, associated with the aircraft and HST journey impact on LAP and climate change (see section 4.3) was calculated and added to the OCs of both modes. According to the 'polluter pays' principle, there is no justification to exempt HST services from environmental charges. The impact from LAP and climate change amounts to €2.98 per aircraft seat on the route, and €0.81 per HST seat on the route. Also, after adding these costs to the base OCs of each mode as an 'impact tax' (Table 16), and although the flight is responsible for more environmental pollution, airlines are not expected to benefit from airline and railway integration on the route. Yet, on a seat-km basis, the advantage of HST over the aircraft increases to €0.019 (25% lower OCs for the HST).

The environmental charge at Swedish airports represents only 3% of the flight OCs and is probably not high enough to encourage airlines to operate new, less polluting aircraft. The proposed Kerosene tax, however, represent 15% of the flight OCs and is probably high enough for airlines, and the ATI, to take account of the environmental implications of aircraft operation, for example through reduced frequency (and a shift to larger aircraft) and through purchase of a newer fleet. The 'impact tax', if applied, would represent 11% of the aircraft OCs and 3% of the HST OCs. It is interesting to note that both the proposed Carbon and Kerosene charges, if applied on a flight from Heathrow to CDG, would make the airlines pay more than the environmental impact actually imposed by the flight, as calculated in this research. However, since those taxes are aimed at all types of aircraft and flights, the analysis actually shows, that for the case study route, they represent a good estimate of the actual impact!

If airlines had to bear the costs of bringing the passengers to Paris city centre, assumed as the passengers' destination, an additional €0.85 per seat would be incurred¹⁴⁹. This would have not changed the base conclusion, and should not be included in the analysis since those costs are not borne by the service operator. Yet it shows that the aircraft advantage over the HST does not stem from the airline service ending at CDG and not at Paris city centre.

4.1.4 Conclusions and discussion

From a methodological point of view, performing a financial analysis is a relatively straightforward exercise. The quality of the analysis, therefore, depends on the quality of data available, which is often restricted due to commercial confidentiality. However, the data available for the analysis in this research is considered good enough to yield a fully robust evaluation, and therefore applicable results.

¹⁴⁹ Using estimates for bus OCs (GAO, 2001) and considering that CDG is 24km from Paris (TCRP, 2000: 71).

The main findings of the evaluation are that for the same unit of capacity and distance (i.e. seat-km) the HST has an OC advantage over the aircraft of €0.012, or 18% lower OCs per seat-km. This suggests that airlines could benefit from OC savings by adopting airline and railway integration, and this might be enough for airline and railway integration to be implemented leading to reduced congestion and to environmental benefits as indicated in section 2.1.5.

However, for the case study route such benefits are cancelled by the longer route for the HST compared with the flight route from Heathrow to Paris. Therefore, airlines adopting airline and railway integration on the case study route would incur OC losses from mode substitution, reducing the likelihood that airline and railway integration will take place on the case study route.

The calculated OCs per seat-km suggest that OC benefits from airline and railway integration would take place as long as the HST route is not more than 21% longer than the aircraft route. The sensitivity analysis showed that the aircraft advantage on the case study route, when OCs are measured in seat per route units, is significant and relatively stable. The HST OCs, in the way calculated here, are only sensitive to the route distance, which is fixed.

The OCs advantage from using aircraft and not HST between Heathrow and Paris diminished, and even cancelled, when environmental charges were imposed on the flight to reflect the impact of aircraft operation on the environment. Yet, the aircraft advantage remains if the HST also 'paid' for its impact on the environment, as calculated in this research.

The analysis above shows that there is currently no reason for airlines to adopt mode substitution unless one or more of the following takes place. First, an environmental tax is imposed on flights but not on HST services, but this is not entirely desirable according to the polluter pays principle¹⁵⁰. Second, airlines have other financial benefits from airline and railway integration which offset the OCs losses. Such benefits could be the benefits of reduced delays or the possible use of the free slots from mode substitution for use of long haul services. Third, benefits to other stakeholder groups (e.g. passengers) are large enough to compensate the airlines for their OC losses.

The decision by airlines whether to operate services, and how much to charge for them, are not always directly related to OCs. Evidence suggests that for some airlines short haul services are not profitable, yet such airlines keep operating these services since they add

¹⁵⁰ The environmental advantage of the HST over the aircraft should be translated into difference in the level of tax and not tax exemption.

value to the airline's network of routes¹⁵¹. In setting fares, companies also consider the demand for their services and the fixed costs already incurred. Thus, under some circumstances, the TOC might charge the airlines less than its full OCs per seat, making it financially beneficial for airlines to substitute an aircraft seat with a HST seat. For example, the marginal OCs of another passenger on board the HST is virtually zero, and therefore in situations where the HST service LF is very low, adding the airline passengers would not result in an OC increase and is therefore beneficial to the TOC at, theoretically, any price paid by the airline. Under these conditions, it is likely that the airline and the TOC would reach a commercial agreement in which the airline would pay for capacity on board the HST at a price which is less than the HST OCs, and less than the aircraft OCs, leading to benefits from airline and railway integration. In the context of the case study route, the market conditions faced by the airlines and an average low LF on board railway services serve as an impetus to the airline and the railway to reach an agreement and to integrate their services (provided the infrastructure for such integration is in place). Despite the above, in the framework of this research the conclusion remains that airlines would lose from operating airline and railway integration.

The differences in OCs between the modes could be reduced through improved efficiency in operating HST services. However, while it is hard to estimate the scope for improved efficiency in operating HST services, the evidence from low cost airlines suggests there is certainly scope for lower OCs for the aircraft which will increase the differences between the modes. Furthermore, when accounting for the aircraft average LF, the efficiency of the aircraft in carrying passengers between Heathrow and Paris is further increased compared to the HST¹⁵². To offset this, the TOC should strive to increase its LF. One of the possibilities to achieve that is by cooperation with the airlines and specifically through airline and railway integration as proposed in this research.

The fact that airlines are likely to lose from mode substitution makes the evaluation of benefits to other stakeholders even more important. The benefits to passengers are analysed next.

¹⁵¹ See López-Pita, 2003; Doganis, 2002b.

¹⁵² Assuming LF of 50% for the HST and 75% for the aircraft results in OCs per passenger of €59.78 and €35.21 for the HST and aircraft service between Heathrow and Paris respectively.

4.2 Evaluating benefits to passengers from the operation of airline and railway integration

Demand for travel is usually considered as a derived demand, i.e. we travel in order to reach a location in which our desired activity takes place. Therefore, travel time, as long as demand for travel is derived, is wasted time. Hence, the main reason for passengers to support changes in the transportation system is expectations of shorter travel times. Also, in the case of airline and railway integration, passengers' support for change in the mode used depends mainly on whether travel time savings are gained. Other benefits that might lead to passengers' support for mode substitution are improved travel conditions, which can lead to a reduction in the disutility from travelling.

Airlines would probably not initiate mode substitution, even when it yielded substantial OC saving, as long as passengers were likely to lose from it. Likewise, airlines would adopt airline and railway integration even when it resulted in OC losses (which is the case on the Heathrow-Paris route) if passengers could substantially gain from it. In this context, benefits to passengers from airline and railway integration were evaluated.

Passengers affected by airline and railway integration are mainly passengers who arrive at a hub airport by a flight and then transfer to a HST service, and not an aircraft service, to complete their journey. This means that the travel time comparison between the HST and the aircraft options of travel (Figure 7 in section 3.1) begins on the second leg of the passenger journey, once the passengers disembark the aircraft on arrival at the hub airport (i.e. Heathrow in the case study route) and start to make their way to the connecting aircraft or HST service.

To improve the analysis, more routes were added to the main case study route. These routes (Table 17) are considered suitable for airline and railway integration to take place on. However, only on one route, Frankfurt airport to Stuttgart, does airline and railway integration take place at present, and this is used as the benchmark case to test for benefits to passengers. On the CDG to Amsterdam route, the hub airport (CDG) is connected to the HST network and therefore infrastructure for airline and railway integration exists. But, on this route there is currently no airline and railway integration. In addition, the HST line between Brussels and Amsterdam (part of the CDG to Amsterdam route) is still under construction. On the main case study route, there is no infrastructure at present to enable airline and railway integration to take place, since Heathrow is not connected to the HST

network. Also added to the analysis is the route Heathrow to Amsterdam. This route is similar to the Heathrow to Paris route, except that the HST route distance is much greater.

In order to use real data for the transfer time between aircraft at the hub airport, it was assumed that, on the Heathrow to Paris and Heathrow to Amsterdam routes, the passenger origin is New York (JFK airport) and BA's schedule was used; on the CDG to Amsterdam, the passenger origin is Athens and AF's schedule was used; and on the Frankfurt airport to Stuttgart route, the passenger origin is Madrid and LH's schedule was used.

Table 17: Routes chosen for analysis of travel time savings

Route	HST Station at hub airport?	HST line along the entire route?	Airline and railway integration?
(NY -) Heathrow – Paris	No	No	No
(Athens -) CDG – Amsterdam	Yes	No	No
(Madrid -) Frankfurt – Stuttgart	Yes	Yes	Yes
(NY -) Heathrow – Amsterdam	No	No	No

Table 18: Components of the aircraft and HST options of travel (based on Figure 7)

Air journey	HST journey
Transfer aircraft to aircraft	Transfer aircraft to HST
Flight to destination city airport	Rail journey to destination city city-centre
Transfer aircraft to railway	
Rail journey to city centre	

To calculate the journey time, the journey was broken into different segments (Table 18). The aircraft journey travel time consists of four segments. It begins with a transfer time between aircraft at the hub airport, then the flight, followed by another transfer between the aircraft and a surface mode, assumed to be rail, at the destination airport. The final segment of the aircraft journey is the travel time from the airport to the destination city city-centre. The HST journey consists of two segments, the transfer time at the hub airport between the aircraft and the HST, followed by the HST journey to the destination city city-centre.

The evaluation of benefits to passengers from airline and railway integration begins by estimating travel time savings from travelling by HST and not by aircraft. Then, potential for benefits from improved travel conditions are evaluated. Finally, the travel time analysis is translated to monetary values by using estimates of the Value of Travel Time Savings (VTTS), based on the methodology described in section 3.3.

4.2.1 Travel-time savings to passengers from airline and railway integration – time based analysis

To calculate the journey time, the schedules published on the relevant operators' web-sites were obtained including the flight time, HST travel time, and transfer time. Where needed, travel time and transfer time were estimated. For each option of travel, two travel times were measured, the **fastest possible at present**, mainly based on the schedule for Summer 2003 (columns A in Table 19), and the **potentially fastest** assuming the shortest feasible transfer time and fastest journey time (columns B Table 19).

On all routes, except for the Frankfurt airport to Stuttgart route, where airline and railway integration takes place at present, improvements to the HST journey are required in order to provide high speed service throughout. On the CDG to Amsterdam route, the HST line between Brussels and Amsterdam is still under construction (EC, 2001). The completion of this line will also influence the journey time on the Heathrow to Amsterdam route. The HST line from London to the Channel Tunnel is also under construction and is expected to be completed by 2007 (Union Railway, 2000). For the routes from Heathrow, the connection of the airport to the HST network is also missing, and is not even planned at present and does not seem plausible in the near future.

Current aircraft service travel times are not expected to improve in the future, and are more likely to deteriorate due to an increase in congestion and delays if the forecasts for growth in demand for air services materialise, even in part¹⁵³. Based on this, travel time differences between the aircraft and HST journeys were measured by comparing current travel time by aircraft (columns A) with HST journey time when the infrastructure for airline and railway integration exists (columns B). This comparison is presented in Table 19 columns C and shows the estimated travel time savings to passengers.

¹⁵³ See section 2.1.4

Table 19: Time based comparison between the aircraft and the HST journeys (Minutes)¹

	(New York-) Heathrow - Paris	(Athens-) CDG - Amsterdam	(Madrid-) Frankfurt - Stuttgart	(New York-) Heathrow - Amsterdam
	Present fastest connection (A) Potentially fastest (B) Air: current Rail: fastest (C: Air = A, HST = B)	A	A (=C) B	A B C
<u>Aircraft journey</u>				
Transfer air-air	<u>50</u>	45	<u>45</u>	<u>65</u>
Air journey	<u>85</u>	60	<u>40</u>	<u>80</u>
Transfer air-rail	60	45	45	60
Surface journey	<u>25</u>	<u>15</u>	<u>27</u>	<u>15</u>
Total Time	220	205	172	220
<u>HST journey</u>				
Transfer air-HST	60	45	<u>45</u>	45
Rail journey	234	160	<u>73</u>	<u>237</u>
Total time	294	308	118	432
Adv. HST (min.)	(-74)	(-103)	54	(-212)
	(-30)	(-41)	39	(-112)
	15	(-16)		(-62)

¹ Underlined travel times are based on real schedule time for summer 2003 taken from the following web sites at 17/05/2003: BA, BAA, SNCF, Aeroports de Paris, Eurostar, AF, LH, Flughafen Stuttgart, and NS.

Transfer time between the aircraft and the HST at the hub airport (Heathrow, CDG and Frankfurt) was assumed to be 45 minutes, the scheduled transfer time at Frankfurt airport. Yet, for the transfer time between the aircraft and the train (the egress mode) at the destination airport (CDG, Schiphol, and Stuttgart airport) 60 minutes were assumed. This represents a 15 minutes faster transfer time between the aircraft and another mode (e.g. HST, rail, metro) under integration compared with no integration, attributed to the fact that the passenger does not need to wait for his luggage, or buy tickets for the onward journey while transferring between integrated services, and assuming better guidance and assistance is provided for integrated services. The transfer time between aircraft at the hub airport is taken from the operator's published schedule.

At present, if passengers opt to use the HST on the case study route, their travel time will be more than one hour longer¹⁵⁴ (Table 19, column A). The current travel time by aircraft is based on the fastest combination of transfer time between the flight from New York and the flight to Paris and the flight to Paris (50 and 85 minutes respectively) (BA, 2003b). In theory, if Heathrow matched the service at Frankfurt airport, transfer time would be as low as 45 minutes, and the fastest flight on the schedule takes 60 minutes. In practice, a transfer time of 60 minutes¹⁵⁵, and a flight time of 70 minutes are probably more realistic according to the timetable, but such a service is not currently provided. To complete the aircraft journey, a transfer time of 60 minutes (or 45 minutes under optimal conditions) and an egress journey of 25 minutes¹⁵⁶ are assumed. The optimal HST journey on the route is assumed to take 2h40m¹⁵⁷. Assuming that the conditions for the aircraft journey are not improved in the future, airline and railway integration is expected to provide 15 minutes shorter travel time on the route if the infrastructure for the HST is provided (Table 19, column C). This advantage will diminish if aircraft-HST transfer time is more than 45 minutes and if the transfer at the destination airport is less than 45 minutes, which in some circumstances might be the case. Applying the same methodology and assumptions to the (Athens-) CDG-

¹⁵⁴ The assumption is that passengers will travel by rail to Paddington station and will then use a taxi to arrive at Waterloo station to board the HST service to Paris. The HST journey time for services before the opening of CTRL section 1 was used.

¹⁵⁵ Out of 20 connections at Heathrow for this route, only two offered 50 minutes transfer time, one 65 minutes, two 85 minutes and the rest much more (BA, 2003b).

¹⁵⁶ The scheduled time for the RER journey from CDG to Gare-du-Nord.

¹⁵⁷ The HST journey Heathrow-Paris was assumed to consist of a 2h15m journey time between London and Paris, once the CTRL has opened (CTRL, 2004) and an additional 25 minutes for the journey from Heathrow to 'London' including the stop at the London railway station. In early publications about the CTRL, e.g. Union Railways (2000), the journey to Paris was estimated at 2h20m.

Amsterdam route shows that airline and railway integration would lead to 16 minutes travel time losses (Table 19, column C)¹⁵⁸.

In contrast to the two routes above, the route between Frankfurt airport and Stuttgart provides much greater time savings benefits. They already take place and are evaluated based on real schedule for both options of travel (LH, 2003). Since LH operates both aircraft and HST services, this route allows airline and railway integration to be tested in practice. Compared to current aircraft services, the HST journey offers 54 minutes faster travel time (Table 19, column A). This advantage remains, but at 39 minutes, if assuming that the transfer time at the destination airport, Stuttgart, is 45 minutes and not 60 minutes (Table 19, column B). It is important to note that part of the advantage to the HST is due to the relatively short distance between Frankfurt airport and Stuttgart (about 200 km).

The Amsterdam-Heathrow route proves to be too long in terms of the HST route distance to provide travel time savings from airline and railway integration.

The travel time savings from airline and railway integration on the routes analysed are not sufficient to make the journey through a hub airport faster than the direct flight. Yet, for different reasons, and mainly higher frequency and airlines' loyalty schemes, many passengers choose to travel via a hub airport. For these passengers, airline and railway integration results in travel time savings on two of the four routes analysed.

The average speed of the HST on the case study route is assumed at almost 200 kph¹⁵⁹. If this decreased or increased by 25 kph, the journey time would increase or decrease by about 20 minutes respectively, substantially altering the benefits from mode substitution on the route. An average speed of 250 kph, possible for the direct service Heathrow-Paris would lead to 34 minutes travel time savings for passengers. However, under the model of airline and railway integration, such services are not assumed. Furthermore, the distance between Heathrow and the connection to the CTRL through a London railway station is assumed to be 30 km and to take 25 minutes. This means that the average speed on this section is 72 kph. If average speed on this section increased to 100 kph, 150 kph, or even 200 kph, then travel time by HST would be reduced by 7, 13, and 16 minutes respectively¹⁶⁰.

¹⁵⁸ Journey time between CDG and Schiphol, once the HST line is completed, is assumed to be 2h42m (IATA, 2003). Additional 14 minutes were added to account for the Schiphol-Amsterdam Central travel time. The completion of the Brussels to Amsterdam HST line is expected to cut journey times on the route by 1h20m.

¹⁵⁹ On the London-Paris section of the route, the average speed is higher at 220 kph. This is considered a good service but it is still slower than the benchmark of 250 kph between Paris and Marseille (Perren, 2001).

¹⁶⁰ The speed on this section has implications for the costs of providing it (see section 5.3.1).

The advantage to the HST, if at all exists, comes from the fact that the HST station is located in the city-centre while the airport, at least on the routes analysed, is not, requiring passengers who travel by aircraft to make an additional transfer and an additional journey from the airport to the city-centre. Given that onboard travel time is relatively constant for a given route¹⁶¹, the possibility to reduce travel time lies mainly in the transfer time between services. Considering the congestion at major airports and on major routes, and specifically at Heathrow, it seems likely that transfer from the aircraft to the HST could be shorter and more reliable than transfer time from one aircraft to another. This depends on the HST station being located within the airport terminal (the Schiphol model¹⁶²).

A framework for aircraft journey time as outlined in Table 20 shows that the HST can compete with a 60 minutes flight if travel time by HST is less than 155 minutes, given that aircraft-HST transfer is 45 minutes. Table 20 can be used to estimate travel time benefits on other routes as well. Once the HST route distance is known, the average speed required to achieve travel time savings from mode substitution can be calculated.

Table 20: Framework for HST and aircraft journey time comparison (minutes)

Aircraft journey		HST journey	
Transfer aircraft to aircraft	60	Transfer aircraft to HST	45
Flight	60	<i>(required) HST journey</i>	155
Transfer aircraft to railway	60		
Rail journey to city centre	20		
Total journey	200		200

To complement the time based analysis, a comparison of aircraft and HST journey characteristics is described next.

4.2.2 Journey and mode characteristics

Passengers' preference for one mode of transport over the other when the two modes offer similar journey time¹⁶³ is influenced by the different characteristics of the journey by each mode, some of which relates specifically to the mode used. These characteristics can, in general, be classified into two categories: safety and comfort.

Both the aircraft and the HST are considered very safe modes, especially in comparison with road modes of transport, and consequently there is no reason to assume a significant difference amongst (most) passengers in the perceived safety degree of the aircraft and the

¹⁶¹ For aircraft services, some variability does exist. Heathrow to CDG flight time ranges from 1h00m to 1h30m, and Heathrow to Schiphol from 1h05m to 1h20m.

¹⁶² See section 2.3.4.

¹⁶³ And journey cost.

HST¹⁶⁴. However, some evidence suggests there is a preference for the journey by HST amongst the general public. Within the general population, 45-50% suffers anything from a slight discomfort to a very intense fear of flying, and “10% of the population suffers from such a high degree of fear or anxiety that it leads them to avoid this means of transport” (Capafons et al, 1999: 260). No similar evidence or research concerning the fear of travelling by train or HST is known. The 11 September terrorist attacks in the US which led to an increased fear of flying might lead to passengers’ preference for the HST. However, there is no evidence that HST services are immune to such attacks¹⁶⁵. Another reason for passengers to prefer the HST over the aircraft in terms of (health) safety is the fear of Deep-Vein Thrombosis (DVT) associated with long-haul flights, but so far “no epidemiological studies investigating the risk of DVT in airline passengers compared to a non-travelling population have been published” (Schobersberger et al, 2003: 20), and DVT is associated with long-haul flights only. In the context of this research, the important point with regard to the above is that most of the passengers using the HST service from the airport have arrived there by a flight!

In terms of comfort there might be perceived differences between the modes. Comfort is a subjective attribute and can be related to many and different characteristics of the journey. In general, comfort while travelling can be described in terms of the “opportunity to engage in other activities while travelling” (Mokhtarian and Salomon, 2001: 702) which leads to a reduction in the disutility from travelling, or the extent to which time is wasted because of the need to travel. Such activities might include sleeping, reading, ‘working’, etc. The possibility to engage in different activities, and the range of activities that might be undertaken, depends on many factors such as the smoothness of the journey, the variety of onboard services, and the seat pitch. These are not necessarily directly related to the mode used, although, due to the vehicle size, the HST might have an advantage over the aircraft in these factors. However, it seems the most important attribute to determine the possibilities in engaging in other activities while travelling is the amount of time available for them during the journey.

On all the routes analysed, the HST option of travel provides longer uninterrupted journey time. This amounts to 1h15m longer uninterrupted travel time on the Heathrow to Paris route (1h41m on the CDG to Amsterdam route, and 13 minutes on the Frankfurt airport to Stuttgart route (Table 21)). On the Heathrow–Amsterdam route, the advantage of the HST in

¹⁶⁴ Real differences in the level of safety between the modes are not expected.

¹⁶⁵ This was proved in the attacks on railway services in Madrid in March 2004, and the discovery of explosions on the HST line Madrid-Seville a few weeks later.

this category amounts to 2h37m, but this is probably not enough to compensate for the longer travel time by HST.

Table 21: Comparison between aircraft and HST journey characteristics

Route	(New York-) Heathrow – Paris		(Athens-) CDG - Amsterdam		(Madrid-) Frankfurt - Stuttgart		(New York-) Heathrow - Amsterdam	
	Air	Rail	Air	Rail	Air	Rail	Air	Rail
Transfers	2	1	2	1	2	1	2	1
Journey segments ¹	5	3	5	3	5	3	5	3
Longest segment of travel ² :	85	160	75	176	60	73	80	237

¹ Transfer between services is considered as a (time) segment.

² Measured in minutes. The flight from origin to the hub airport (e.g. from New York to Heathrow) is not included.

The number of interruptions to the journey is also an indication to the possibility to engage in other activities. Under the model of airline and railway integration, passengers travelling by HST are required to interrupt their journey and transfer between services only once, compared to two transfers when they travel by the aircraft (Table 21). The high value passengers assigned to time spent transferring between services (see below) is an indication of the disutility passengers experience from having to interrupt their journey and change between services.

The analysis of the journey characteristics suggests that the HST has an advantage over the aircraft because it offers a longer uninterrupted journey and requires one less transfer between services. These are assumed to be positively valued by passengers, and it might make the HST the passengers' choice, even if travel time by HST is a few minutes longer than the travel time by aircraft.

4.2.3 Travel-time savings to passengers from HST and aircraft substitution – a monetary based analysis

To compare the benefits to passengers with other benefits from airline and railway integration, a monetary value was assigned to the travel time savings on the case study route. These savings were assumed for this analysis to be 15 minutes. Although these time savings were sensitive to the assumptions made, they are considered to be a reasonable consequence of airline and railway integration on the case study route.

The methodology to estimate the monetary value of travel time saved due to airline and railway integration (described in section 3.3) is based on applying the most appropriate value

of travel time savings (VTTS) estimates for the two options of travel compared in this study. The results are described in Table 22.

The analysis begins by applying the EU recommended VTTS estimates (EUNET, 1998) as the base case. The recommendations are to use a single VTTS estimate for time spent travelling for non-work purposes regardless of the mode used, and differentiation by mode when time spent travelling is during working time. The transfer time between the modes should be valued at 1.6 the value of time (VOT) spent travelling¹⁶⁶. Using this set of estimates yields travel time savings from airline and railway integration of €4.05 for leisure passengers, i.e. passenger on non-work journeys. The savings/benefits for business passengers, i.e. passengers on journeys taken during work-time, amount to €61.68 (Table 22, column 1).

Wardman (2001a) estimates an interchange penalty of 17.6 minutes, which represents the “disutility of having to change over and above that associated with the time spent waiting for or transferring between trains” (ibid: 112, my emphasis). Applying this assumption to the leisure and business journeys¹⁶⁷ yields an advantage from using the HST of €6.16 and €79.38 respectively ((Table 22, column 2). A different research estimates that air travellers’ VOT on connecting intercontinental flights is over \$150 per hour, which “probably reflect[s] marginal values for the extra time...instead of average values for the entire flight. This may also imply that the VOT estimation also contains the disutility of the connecting (sic)[¹⁶⁸] and the higher valuation of waiting time involved” (Lijesen et al, 2002: 249). Applying the above value¹⁶⁹ to the transfer time results in a VTTS of €158.75 for leisure passengers and €164.83 for business passengers (Table 22, column 3). An advantage in using this value is that it is the most appropriate for the context of this research, hence more likely to represent the true disutility from the need to transfer. However, the fact that it does not differentiate between leisure and business passengers is a limitation. More important, no other study which suggests such a high value was found.

¹⁶⁶ This means that every minute of time spent transferring between services equals 1.6 minutes of time spent travelling on board (see section 3.3).

¹⁶⁷ Adding 17.6 minutes to the transfer time and then multiplying by 1.6 to account for the base transfer value (EU transfer value).

¹⁶⁸ It is assumed that the correct word is “connection”. In an earlier version of this paper (Lijesen et al, 2001), the word “layover” was used.

¹⁶⁹ This translates into €2.50/minute.

Table 22: Monetary based comparison between the aircraft and the HST journeys (Euro)

	1	2	3	4	5	6
Time (min.)	EU policy	Adding transfer penalty (17.6 min)	Valuing transfer at €2.50/min.	Mode specific VOT 1 (UK est.)	Mode specific VOT 2	Mode specific VOT 3
VTTs parameters						
AIR (Euro/min)	Leisure 0.08 Business 0.63	Leisure 0.08 Business 0.63	Leisure 0.08 Business 0.63	Leisure 1.11 Business 1.24	Leisure 0.37 Business 0.46	Leisure 0.57 Business 0.63
HST (Euro/min)	0.08	0.08	0.08	0.18	0.23	0.15
Urban rail (Euro/min)	0.08	0.08	0.08	0.09	0.10	0.09
Transfer air-air (x IVT, * Euro/min)	1.60	1.60	2.50*	1.60	1.60	1.60
Transfer air-rail (x IVT, * Euro/min)	1.60	1.60	2.50*	1.60	1.60	1.60
Air journey VOT						
Transfer air-air	6.00	8.11	125.00	89.04	29.60	45.60
Air journey	6.38	6.38	6.38	94.61	31.45	48.45
Transfer air-rail	7.20	9.31	150.00	8.64	9.60	8.64
Surface journey	1.88	1.88	1.88	2.25	2.50	2.25
Total Value of Time	21.45	25.68	283.25	194.54	73.15	104.94
HST journey VOT						
Transfer air-rail	5.40	7.51	112.50	12.96	16.56	10.80
Rail journey	12.00	12.00	12.00	28.80	36.80	24.00
Total Value of Time	17.40	19.51	124.50	41.76	53.36	34.80
Advantage HST (VTTs, Euro/journey)	15	6.16	158.75	152.78	19.79	70.14
						69.14

The EU favours the use of the same VTTS for all modes when the journey is not during work time, but there are many arguments, and empirical evidence that support mode specific VTTS also for leisure journeys¹⁷⁰. The problem is then which estimates to use in this analysis.

The first set of VTTS chosen for the analysis is the UK VTTS estimates (Wardman, 2001b) for air travel, intercity rail travel (for the HST journey), and 'urban' rail (for the surface journey CDG to Paris). When using these estimates, and a transfer value as recommended by the EU, the VTTS from using the HST and not the aircraft is €152.78 for leisure travel, and 135.19 for business (Table 22, column 4). These estimates, however, yield a result in which the leisure passenger benefits more than the business passengers from the same 15 minutes travel time savings, which is not consistent with the theory of the VTTS.

Under airline and railway integration, the journey characteristics of the aircraft and the HST are likely to be similar. Therefore, the differences between the aircraft VTTS and the HST VTTS should be smaller. Using higher VTTS estimates for the rail¹⁷¹ and changing the flying VTTS to €0.37 and €0.46 per minute for leisure and business travel respectively (values estimated in Sweden¹⁷² (Bråthen et al, 2000)), and applying this set of values results in a positive VTTS for leisure passengers who travel with the HST of €19.79, but a negative VTTS for business passengers who choose the HST over the aircraft (Table 22, column 5), which is inconsistent with the theory. An alternative set of values used is based on an average of the available estimates for each particular mode. This also results in (slightly) higher VTTS for leisure passengers (Table 22, column 6)¹⁷³.

Assigning a monetary value to the travel time saved as a result of airline and railway integration proved to be problematic in this research and leads to varying results. In addition to variation in the results, some are not consistent with the theory, although the analysis is based on acceptable assumptions, common practices in transportation projects appraisal, and robust academic research. In general, it was not possible to find 'best practice' for this research partly because governments and the EU support the use of a single value for

¹⁷⁰ See section 3.3.3.

¹⁷¹ Estimates by rail passengers, as opposed to estimates by the general population of travellers, of rail journey according to distance were used. Rail passengers' VTTS for journeys of 16 km (10 miles category) were applied for the surface journey CDG-Paris and rail passengers' VTTS for journeys of 320 km (200 miles category) were applied to the HST journey Heathrow-Paris (Wardman 2001b).

¹⁷² The EU non-working VOT for the UK is €0.065/minute and for Sweden is €0.063 (EUNET, 1998) suggesting the Swedish values can be a good estimate for the UK values.

¹⁷³ It is important to note that, for both the HST journey and the aircraft journey, the journey VOT is higher for the business passenger, which is consistent with the theory, but the differences between the two options of travel lead to higher VTTS for the leisure passenger for the same travel time savings, which is not consistent with theory.

different modes but empirical evidence suggests that passengers do value differently the travel time on different modes. The above reinforces Gunn's (2003) view that "while new research...takes forward our understanding of the subject [of valuing travel time], it also raises some important questions about how differences between observation and theory should be reconciled" (ibid: 12). It also reinforces the limitations in applying estimates from different studies onto a specific, but different, project or study.

The best solution in the context of this research is to conduct a survey designed specifically to evaluate the appropriate VTTS. Such an approach is also supported by the CfIT, which advocates the use of a project specific VOT to evaluate the construction of HST lines in the UK (CfIT, 2004). However, the international characteristic of the journey and the passengers imposes problems in performing such a survey, even if other obstacles are overcome, since each passenger (whether traveling for business or leisure purposes) is likely to have different values depending on his country of origin. Furthermore, the multi-modal characteristic of the journey analysed requires that a specific value be estimated for each mode, as well as for the different transfer segments¹⁷⁴, and amongst all aircraft passengers on the route, the relevant population for this research.

Despite the limitation in the VTTS analysis, it is important to assign a monetary value to the travel time savings found in order to compare benefits to passengers with other benefits and with the costs of connecting Heathrow with the HST network. Using the set of estimates recommended by the EU (Table 22, column 1) seems to be the least unfavourable and was therefore adopted. It was justified in part due to the international characteristics of the route. Combining these estimates with Lijesen et al (2002) estimate for transfer time seems an even more appropriate approach but since no other evidence for such a high value of transfer time was found, this was rejected. It is important to note that, except for one estimate (business journey in Table 22, column 5), using the EU recommended values yielded the lowest benefits from travel time savings.

4.2.4 Conclusions

The analysis of benefits to passengers from airline and railway integration showed that time-based analysis is the most robust way to assess the benefits to passengers in this research. Hence, if travel time savings occur following airline and railway integration, it can be concluded that passengers will benefit from it. In addition, following integration, passengers

¹⁷⁴ The way time spent transferring between services is measured, i.e. a multiplication of the time spent in-vehicle, means that because the HST VTTS is usually lower than the aircraft VTTS, the transfer time from the aircraft to the HST is valued less than the transfer time from one aircraft to another. In the context of this research, there should not be such a difference.

would benefit from improved journey characteristics, including one less transfer during the journey and longer uninterrupted travel time, which allows better opportunities to engage in different activities while travelling. However, in the absence of travel time savings it is not possible to determine if better journey characteristics are enough for passengers to benefit from mode substitution.

The time based analysis concluded that passengers on the route Heathrow-Paris would enjoy travel time benefits, hence would benefit from airline and railway integration. For these benefits to materialise, the following must take place. The hub airport (Heathrow) must be connected to the HST network; a HST service, or a HST line, must exist throughout the route; the airline and the railway services must be integrated to ensure quick and smooth transfer time, as well as coordinated scheduling of the services (to reduce the transfer time); and the hub airport needs to be equipped to offer 45 minutes transfer time (of both passengers and their luggage). The Frankfurt airport - Stuttgart route where the above conditions are met demonstrates that time savings to passengers from airline and railway integration can take place.

The 15 minutes travel time savings found for the case study route are sensitive to the assumptions used, yet they are considered robust for several reasons. For the aircraft journey, the shortest connection and flight time were used, and these are likely to increase in the future with the increase in congestion. In addition, most connections at Heathrow are significantly longer than the one used¹⁷⁵. In part this is due to congestion at Heathrow which does not allow airlines (and mainly BA) the scheduling flexibility necessary to achieve better coordination between flights (Doganis, 2002b). For the HST, the travel time used is the planned travel time between London and Paris once the CTRL is completed, plus a relatively slow service, hence realistic, on the Heathrow-CTRL section. Also the assumption that the transfer time aircraft to HST at Heathrow is 15 minutes longer than the aircraft to egress journey transfer at CDG is reasonable, as explained above. However, the sensitivity of the travel time savings to the aircraft to HST transfer time emphasized the importance of achieving 45 minutes transfer time, as in Frankfurt airport.

The limitations in the monetary analysis of travel time benefits suggest that the results obtained (based on the EU estimates) should be viewed as an indication. Nevertheless, important conclusions can be drawn from the analysis. Although the shorter the travel time the better it is from the passenger's perspective, there is a big difference in what segment of the journey travel time is saved. The analysis clearly indicates that operators' efforts to

¹⁷⁵ Rietveld and Brons (2001) found that the average waiting time between services at Heathrow is 2h04m.

reduce travel time should be concentrated on reducing the transfer time and on reducing the inconvenience associated with the transfer and the need to interrupt the journey¹⁷⁶. In addition, the inconvenience of the transfer, which is reflected in the high VTTS, is also associated with the “additional risks of missing connections and loss of luggage” (IATA, 2003: 195). This emphasised the importance of integration in mode substitution. As the transfer time is reduced, the risk of missing the connecting (HST) service increases and with it the VOT. However, if the passenger is guaranteed a place on the next service, at no extra charge, which is the norm when the two services are offered by the same service provider (or under code share agreement), then this can reduce the VOT.

In conclusion, the analysis of benefits to passengers showed that such benefits could materialize on the case study route if airline and railway integration takes place. Next, benefits to society in the form of reduced environmental impact are analyzed.

¹⁷⁶ This is reinforced by considering that the transfer value suggested by the EU is probably an underestimate.

4.3 Evaluating the benefits to society of reduced environmental impact from operating airline and railway integration

Based on the methodology described in sections 3.1 and 3.4 environmental benefits from airline and railway integration, assumed to be enjoyed by society, were evaluated. Below, a series of tables are used to present the main results accompanied by analysis of the findings. In general, each option of travel is evaluated separately and the differences between them represent the benefits from mode substitution under airline and railway integration. This is followed for evaluation of benefits from reduced local air pollution (LAP) and climate change following airline and railway integration. For benefits of reduced noise impact, the comparison is of a different nature due to data and methodological obstacles.

4.3.1 Measuring potential reductions in local air pollution from shifting services from the aircraft to the HST

4.3.1.1 Emission from the aircraft and HST journeys

Following the methodology described in section 3.4.2, aircraft and HST impact on LAP is first evaluated by estimating emission emitted during the journey by aircraft and by HST. The results are presented for the aircraft, the egress modes, and the HST, first separately and then together to compare the two options of travel.

Table 23: Emission during the LTO cycle for A320 and B737 (gr/seat/mode)

LTO cycle stage	TIM (min)	HC	CO	NO _x	SO ₂	PM ₁₀	Total
Take-off (A320)	0.7	0.1	0.5	14.5	0.3	na	15.5
Climb-out (A320)	2.2	0.3	1.4	29.7	0.8	na	32.3
Approach (A320)	4.0	0.4	2.3	7.4	0.5	na	10.7
Idle (A320)	26.0	2.9	37.0	8.4	1.1	na	49.5
A320 total per LTO cycle	32.9	3.8	41.2	60.1	2.8	1.6 ¹	109.5
B737 total per LTO cycle	32.9	5.3	93.6	65.8	3.6	1.6	169.9

¹ The estimate for the B737 is used in the analysis for the A320 PM₁₀ emissions. Source: Based on EPA (1999b).

Table 23 shows the amount and mix of gases emitted during the LTO cycle of an A320. Most of the emission is emitted during the idle mode, the longest mode, followed by emission from the climb-out mode where the high engine thrust, rather than the Time In

Mode (TIM), is the main contributor to the high level of emission¹⁷⁷. NOx and CO are the most plentiful gases emitted, far more than emissions of HC, SO₂, and PM₁₀. Compared with the B737, the operation of the A320 results in less emission across all pollutants. This can be attributed to economy of scale in aircraft operation (the A320 capacity is 150 seats compared to 128 seats for the B737), and perhaps to advances in technology (the A320-200 entered service in 1988 and the B737-300 in 1984 (Endres, 2001)). It is important to note, however, most of the A320 advantage comes from reduced CO emission (87% of the difference between the models), while a relatively minor reduction is achieved in emission of NOx. The significance of this can only be realized once the impact caused by each pollutant is analysed.

Emissions during the LTO cycle depend on the assumed height of the mixing zone. This was assumed to be 915m, the ICAO standard, and might be considered more as an upper limit rather than as a central estimate (see section 3.4.2). Assuming a lower mixing zone will affect emissions during the climb-out and approach stages only. Lowering the mixing zone by more than half of the original estimate to 450m, probably an under estimation of the average mixing zone, shortens the LTO cycle by 3.4 minutes only to 29.5 minutes and reduces total emission by 25 grams, 21.9 of which is due to reduced NOx emission.

Table 24: Emissions during the egress journey (gr/seat/route¹)

Mode	HC	CO	NOx	SO ₂	PM ₁₀	Total
Car (4 seats)	10.9	67.2	6.2	0.1	0.2	84.6
Bus (70 seats)	0.6	3.8	0.4	<0.1	<0.1	4.8
Total ²	7.7	47.6	4.4	0.1	0.1	59.9

¹ Route: CDG-Paris city centre, 24km.

² Modal split at CDG: 69% car, and 39% public transport (assumed to be bus services).

Source: based on CfIT (2001a).

Emission from the egress mode depends on the modal split between car and public transport, since emissions from cars are far greater than emissions from buses. For consistency throughout the analysis, the vehicle capacity rather than the average LF was considered. Considering a 69% and 39% modal split between car and bus respectively, emission attributed to the egress journey were calculated (Table 24). CO emissions are the most dominant pollutant, representing almost 80% of total emissions.

For HST emission, two estimates were used in the analysis: one for the TGV (Quinet, 1994), and one for the UK West Coast Main Line (WCML, the London-Manchester route (CfIT, 2001a). Emissions rates for the TGV are given in gram per passenger-km units and were

¹⁷⁷ See Table 8 in section 3.4.2

converted to units of seats by assuming a 45% LF¹⁷⁸. The two estimates used represent two different types of train and differences in the mix of sources used to generate electricity in the UK and France¹⁷⁹. An average of the two estimates was derived and used (Table 25). For the TGV, an estimate of Aerosols emissions is given, while for the WCML an estimate of PM₁₀ (a sub-group of Aerosols) emission is given. The latter is used for comparison with the aircraft journey. Table 25 shows that emissions of SO₂ are the primary pollutant from the HST journey, followed by emission of NO_x. Compare to these pollutants, emissions of CO, PM₁₀, and HC are almost insignificant in quantity. The much higher rates of SO₂ emission from the WCML probably represent the higher dependency on coal to generate electricity in the UK.

Table 25: Emissions from the HST journey (gr/seat/route¹)

	HC	CO	NO _x	SO ₂	Aer./PM ₁₀	Total
TGV ³	0.5	1.2	16.8	29.3	10.4 (Aer.)	58.1
WCML ⁴	0.4	3.3	18.3	41.5	1.0 (PM ₁₀)	64.5
Average	0.5	2.2	17.6	35.4	1.0 (PM ₁₀) ²	56.6

¹ Route distance 525 km (see section 3.1).

² The PM₁₀ estimate for the WCML is adopted for the rest of the analysis.

Source: based on ³Quinet (1994), and ⁴CfIT (2001a).

Table 26: Comparison of emission from the aircraft and HST journey (gr/seat/route¹)

	HC	CO	NO _x	SO ₂	PM ₁₀	Total
Aircraft (a)	3.8	41.2	60.1	2.8	1.6	109.5
Egress journey (b)	7.7	47.6	4.4	0.1	0.1	59.9
Aircraft journey (a+b)	11.5	88.8	64.4	2.9	1.8	169.4
HST journey	0.4	2.2	17.6	35.4	1.0	56.6

¹ Route: Heathrow to Paris

The above findings are summarised in Table 26 in order to compare emissions from the aircraft and the HST journeys on the case study route. The journey by aircraft results overall in three times more emissions of pollutants than the HST journey. Much more striking is that emissions from the egress journey alone are more than the whole from the HST journey. Other than emissions of SO₂, the journey by aircraft results in more emissions across all pollutants compared with the HST. HC, and CO emissions from the egress journey are higher than emission of the same pollutants from aircraft and HST. Assuming a mixing zone height of 450m, the journey by HST will still result overall in less emission than the aircraft.

¹⁷⁸ 45% LF for the HST assumed in this research (i.e. 766 seats). CfIT (2001) estimate an average 33% LF for the routes analysed in their study; Reitveld (2002) estimates 27% and 48% as the off-peak and peak LF respectively in the Dutch rail network. However, the data on the HST services of the TOC described in the financial analysis (4.1) show a 47% LF. A 5% increase or decrease in the LF leads to about a 10% increase or decrease respectively of emission rates per seat unit.

¹⁷⁹ In France (1998): 76.2% Nuclear and 12.5% Hydro electric. In the UK (1998): 48% Coal-fired, 22% Gas, and 18% Nuclear (Turner, 2002).

The difference between the modes in NOx emissions would be reduced by 21.5 grams per seat, in this case.

4.3.1.2 Impact on LAP from the aircraft and HST journeys

Comparing total emission between the aircraft and HST journeys means assuming that all pollutants have the same (negative) impact on the environment, but this is not the case. Each pollutant's impact on LAP has a different magnitude which must be accounted for. In this respect, unless one option results in more emission across all pollutants, which was not the case above, the comparison of total emissions might be misleading. To take account of each pollutant's impact on the environment, its toxicity factor was considered (Table 27).

The toxicity-factor analysis confirms the impression from Table 27 that the journey by HST results in less impact on LAP than the journey by aircraft. It shows that the aircraft journey impact on LAP is 65% higher than the HST journey. It also shows that the egress journey contribution to LAP is significant but less than the HST journey contribution (this is mainly due to the low toxicity factor of CO emissions). NOx emissions from the aircraft appear to have the most impact on LAP due to their high volume and high toxicity factor, followed by SO₂ emissions from the HST. The relatively low volume of Aerosols and HC emitted during the HST journey result in a relatively low impact on LAP despite the high toxicity factor, but the impact on LAP from HC emissions associated with the aircraft journey is significant. Finally, for emission of CO the low toxicity factor leads to a low impact on LAP despite the high volume of emission. Table 27 suggests that the focus, in terms of monitoring and improving LAP, should be on NOx and SO₂ emissions.

Table 27: Comparison of emissions from the aircraft and HST journey using toxicity factors (toxicity factor units/seat/route)

	HC	CO	NOx	SO ₂	Aer. ²	Total
Toxicity factor¹	100	1	125	100	100	
Aircraft (a)	380	41	7,510	278	164	8,372
Egress journey (b)	773	48	547	8	13	1,388
Aircraft journey (a+b)	1,153	89	8,056	286	176	9,760
HST journey	45	2	2,197	3,539	100	5,882

¹ Source: Quinet (1994).

² Aerosols – the toxicity factor refers to aerosols, although emissions of PM₁₀ were measured.

The toxicity factor analysis is relatively sensitive to the assumptions on the height of the mixing zone and the car capacity, but less sensitive to the aircraft type. In all cases, the differences in the journeys' toxicity factor are mainly due to changes in NOx emissions. When the height of the mixing zone is set at 450m, the flight results in 5,522 units of toxicity

(36% reduction in NOx emission to 4,777 units), lower than the HST journey (but the HST journey remains the better option of travel due to the egress journey contribution to LAP). Changing the car capacity to one seat, the egress journey impact on LAP rises to 5,449 toxicity units (3,033 and 2,146 units for HC and NOx emissions respectively), which means the egress journey contributes to LAP almost as much as the whole HST journey. Finally, changing the aircraft model to B737 leads to a 996 units increase (almost 12%) in the flight's toxicity factor.

4.3.1.3 The cost of LAP from the aircraft and HST journeys

Table 28 presents two sets of estimates for the cost of LAP caused by each pollutant. The uncertainty associated with quantifying the cost of LAP is represented by the fact that both sources of these sets (Lu and Morrell (2001) and Dings et al (2002a)) use an average of the estimates they found in different studies, and the fact that those estimates vary considerably across the studies used to derive the average. The two sets of estimates are based on completely different studies.

“Knowledge about the damage costs of air pollution has improved vastly in recent years. Progress has been particularly marked with respect to the health effects of transport pollutants” (Dings et al, 2002a: 53). The smaller variation of the estimates across the studies surveyed by Dings et al (2002b) compared with the ones surveyed by Lu and Morrell (2001), seems to support that¹⁸⁰. For NOx emission, both studies reach a similar average, but in the former study the range of estimates is €9-12 per kg, and in the latter the range is €1.26-17.6 per kg. The same pattern appears in the estimates for SO₂ (€3.3-8.5 per kg in the former, and €7.85-121.43 per kg in the latter). All the studies surveyed by Dings et al (ibid) show the damage from NOx emission to be higher than the damage from SO₂ emission, while all the studies covered by Lu and Morrell (ibid) show the opposite. This is of particular importance since the difference between the aircraft and the HST depends mainly on the cost of damage caused by SO₂ emission compared with NOx emission. It is important to note the inconsistency between the estimates for the cost of LAP and the toxicity factor estimate across the pollutants. The toxicity factors, however, suggest that NOx emission is more damaging than SO₂ emission. Finally, Dings et al (2002a) do not include CO emission in their study since it does not appear to give rise to significant health effects¹⁸¹; this is supported by the Lu and Morrell (2001) estimate.

¹⁸⁰ Dings et al (2002b) survey three studies from 1999 and one from 2000, and Lu and Morrell (2001) survey one study from 1996, two from 1997, and one from 1998.

¹⁸¹ Pearce and Pearce (2000) arrive at the same conclusion.

Table 28: Damage cost estimates for different pollutants (Euro/kg, 1999 prices), and the toxicity factor

	HC	CO	NOx	SO ₂	PM ₁₀
Dings et al (2002a)	4	na	9	6	150
Lu and Morrell (2001)	3.29	0.07	9.12	48.74	106.0 ⁽¹⁾
Toxicity factor (Toxicity units) ²	100	1	125	100	100

¹ Mayers et al, 1996.

² Quinet, 1994.

The average cost estimates derived by Dings et al (2002a) are used in the analysis since they are based on more up-to-date studies which were relatively consistent in their estimates¹⁸². The 'average' is across studies, but also an average of the cost of damage caused by emission in urban and rural areas representing different sizes of population exposed to emission. Assigning the cost estimates to the emission from both options of travel shows that the journey by aircraft leads to more damage than the journey by HST, by €0.39 per seat (Table 29). Most of the damage from LAP caused by the aircraft journey is attributed to NOx emission, followed by PM₁₀ emission (64%, and 29% of the total cost respectively). Most of the cost of LAP from the HST journey is attributed to SO₂ emission, followed by PM₁₀ emission (41%, and 29% respectively). The LAP from the egress journey is almost 10% of the LAP from the aircraft journey in cost terms.

Table 29: Comparison of the cost of LAP imposed by aircraft and HST journeys (Euro/seat/route, 1999 prices)

	HC	CO	NOX	SO2	PM10	Total
Euro/kg emission	4.00	0.07	9.00	6.00	150.00	
Aircraft (a)	0.015	0.003	0.541	0.017	0.245	0.82
Egress journey (b)	0.031	0.003	0.039	0.001	0.019	0.09
Aircraft journey (a+b)	0.046	0.006	0.580	0.017	0.265	0.91
HST journey	0.002	<0.001	0.158	0.212	0.150	0.52

The results are relatively sensitive to the assumption on the height of the mixing zone (LAP caused by the flight amounts to €0.61 when this is assumed at 450m), and the car capacity (LAP from the egress mode rise to €0.37 when one seat is assumed for the car), but the conclusion that the HST journey results in less damage from LAP remains.

When assigning the cost estimates derived by LU and Morrell (2001)¹⁸³, the aircraft journey imposes a cost of €0.96 per seat, which is similar to the estimate in Table 29, but the HST

¹⁸² These estimates were also used in a report submitted to the CfIT (Wit et al, 2003) and later adopted by it (CfIT, 2003). Lu and Morrell (2001) estimate for CO is adopted in the analysis.

¹⁸³ Estimating directly from Mayeres et al (1996) the value for PM₁₀. This study is included in Lu and Morrell (2001) research but not PM₁₀ emission.

journey imposes a cost of €1.99. Accepting Lu and Morrell's (ibid) estimates would lead to the conclusion that the journey by HST results in more LAP (the main reason for this is the very high cost estimate for SO₂ emissions of €48.74 per kg). This clearly shows the uncertainty associated with estimating environmental impact in monetary units. The reasons for preferring Dings et al (2002a) estimates were outlined above.

4.3.1.4 Measuring potential reductions in local air pollution from shifting services from the aircraft to the HST – conclusions

One of the main environmental impacts associated with transport operation is its effect on LAP. Major airports are specifically notorious as areas of a high level of air pollution; very often as polluted as city centres. The main sources for high air pollution levels around airports are the aircraft (when the engines or the auxiliary power unit are operating), the surface traffic to and from the airport (mainly car traffic), and the surface traffic inside the airport air-side area. All these can be eliminated if services would have shifted to the HST, but then LAP caused by the HST must be considered. Surprisingly, the effect of aircraft operation on LAP does not, usually, get much attention, if at all, despite sufficient data and the potential to contain this impact since it is local¹⁸⁴. The importance of the analysis described above, in addition to its importance in the context of airline and railway integration, is thus clear.

For estimating aircraft emissions '1st best' data was available (the exception being data for PM₁₀ emission) while for the HST the data might be considered as 2nd best. The robustness of the analysis thus stems from the available data on emission. The weaknesses, however, stem from the many assumptions required, and the uncertainty concerning estimates of the impact and the cost of emission. This suggests that the evaluation of LAP caused by an aircraft and a HST journey, on the case study route, should be regarded as a good indication for LAP, but not necessarily an accurate one.

The results of the analysis are summarised in Table 30. Although the comparison of emission shows that the HST journey results in significantly less emission than the aircraft journey, this should not lead to a conclusion that the HST causes less LAP¹⁸⁵, since the aircraft journey does not result in more emission across all the pollutants. Yet, the toxicity and the cost analyses allow (a methodologically robust) comparison between the two options of

¹⁸⁴ The attention usually focuses on climate change impact, and noise pollution. For example, Environmental Audit Committee (2003), and Upham et al (2003). In the former, LAP was not considered under "quantifying environmental cost" and in the latter the book, entitled "towards sustainable aviation", devote one paragraph for aircraft operation impact on "outdoor air quality".

¹⁸⁵ This was demonstrated when Lu and Morrell (2001) cost estimates were used.

travel since they account for the relative impact/damage caused by each pollutant. While using the toxicity and cost indicators allow a comparison between the modes, it reduces the conclusion's robustness since it means losing scientific certainty and adding subjectivity to the analysis (see section 3.4.1). Accounting for the limitations of using these indicators, both analyses show a significant advantage to the HST journey over the aircraft journey, and hence show that airline and railway integration on the case study route would yield benefits of reduced LAP.

The analysis clearly showed that emission of NO_x (mainly from aircraft) and SO₂ (mainly from the HST) contribute the most to LAP. PM₁₀ emission appears important in the monetary analysis. This is probably due to the recognition in recent years (that leads to more research and monitoring) of the health effects associated with this pollutant (Dings et al, 2002a). The analysis also indicated the significant contribution to LAP from the egress journey. This was apparent in all the levels of the evaluation, yet it was not the determining factor in deciding which option of travel should be preferred¹⁸⁶.

Table 30: LAP indicators from aircraft and HST journey (seat/route units)

		HC	CO	NO _x	SO ₂	PM ₁₀	Total
Emissions (gram)	Aircraft	11.5	88.8	64.4	2.9	1.8	169.4
	HST	0.4	2.2	17.6	35.4	1.0	56.6
Impact (Toxicity units)	Aircraft	1,153	89	8,056	286	176	9,760
	HST	45	2	2,197	3,539	100	5,882
Cost (Euro)	Aircraft	0.046	0.006	0.580	0.017	0.265	0.91
	HST	0.002	<0.001	0.158	0.212	0.150	0.52

In order to quantify the benefits of reduced LAP from airline and railway integration, it is necessary to decide whether the toxicity or the cost estimates are more robust. The methodological framework used for the analysis¹⁸⁷ suggests that the toxicity factor analysis is more robust since it represents an earlier stage in the pathway to evaluate transport operation impact on the environment. However, no other study that uses the toxicity factor was found, and the factors are relatively dated (based on a 1987 study). This justifies reliance on the monetary evaluation. Furthermore, both indicators show a relatively similar advantage for the HST; the aircraft journey results in 66% more toxicity units, and 75% higher cost of damage from LAP.

¹⁸⁶ It is interesting to note that if the case study route was London city-centre to Paris city-centre, the analysis would remain unchanged, except (almost) doubling of the egress journey emissions to take account of the access journey to Heathrow.

¹⁸⁷ Described in section 3.3.1 and illustrated in Figure 11.

Air pollution is determined by where emission takes place as much as by how much emission is emitted. Therefore, the number of people exposed to emission around airports (from aircraft during the LTO cycle and from the egress journey) and the number of people exposed to emission from power plants (assuming they are the main source of energy supply for the HST) must be compared. It can be assumed that airports are built closer to populated areas than power plants are. Thus, more people are exposed to emissions from the aircraft journey than to emissions related to the HST journey. This is, however, not accounted for in the analysis above. Dings et al (2002a) provide cost estimates for rural and urban areas. Assuming that power plants are built in rural areas and major airports closer to urban areas and accordingly apply the rural damage estimates for the HST journey and the average estimates (used in Table 29) for the aircraft journey, the advantage of using the HST rises to €0.58 per seat (the cost of LAP from the HST is €0.34)¹⁸⁸.

The balance between the modes can change in the future depending on each mode's potential to reduce emission through either technological improvements (e.g. improved fuel efficiency) or a change in the source of energy used (or both). On the latter, the literature suggests a greater potential for reduction in emission lies with the HST, on the former no comparable evidence was found¹⁸⁹.

In terms of changing the 'fuel' used, the differences that already exist between the sources of energy in France and the UK show the scope for improvement on the UK side, since emissions will vary with the level of renewable sources used. The CfIT (2001) predict changes in the future electricity generation mix in the UK with less reliance on coal (the main source of SO₂)¹⁹⁰. Chaaban et al (2004) examine three methods to reduce SO₂ and other gas emission from power plants: switching to low-sulfur fuel oil, filtering stack emissions, and shifting to natural gas as an alternative fuel; none of these options is available for aircraft. The RCEP view is that "kerosene will remain the fuel for air travel for the foreseeable future" (RCEP, 2002: 28)¹⁹¹. However, Table 25 shows that currently in France, where much of the electricity is produced using 'clean' sources, HST operation results in significant emission of SO₂.

¹⁸⁸ When for the aircraft the urban, as opposed to the average, estimates are used the benefits increase to €1.07 per seat.

¹⁸⁹ The potential for improved fuel efficiency in aircraft is briefly discussed in 2.1.2.

¹⁹⁰ These predictions are reinforced by policies outlined in the UK Government Energy White Paper published in 2003 (DTI, 2003).

¹⁹¹ The RCEP concludes that "even if hydrogen should come into widespread use as a transport fuel, it will be used first for surface transport for which both storage and use will bring greater benefits with less difficulty than for air travel...Other possible fuels generally lack the operational benefits of kerosene, or even hydrogen" (RCEP, 2002: 28).

In summary, the analysis clearly shows potential for benefits of reduced LAP from airline and railway integration. These benefits, and the difference between aircraft and HST, depend mainly on the amount of NO_x emitted during the aircraft LTO cycle, and the amount of SO₂ emitted from the production of electricity used for HST operation. Emission of PM₁₀ also has a significant contribution to LAP, while the contribution from HC and CO emission is not significant. As more research on the affects of NO_x, SO₂, and PM₁₀¹⁹² is carried out and more knowledge gained, the evaluation of such benefits will become more robust. This would probably be evident in convergence of the estimates used to indicate transport operation impact on LAP.

The overall implications of the LAP analysis for airline and railway integration are further discussed in section 4.3.4.

4.3.2 Measuring potential reductions in climate change from shifting services from the aircraft to the HST

4.3.2.1 Emission from the aircraft and HST journeys

To evaluate the impact a flight has on climate change, the whole flight, from the moment the engines are turned on until they are turned off, must be considered. The best estimate for the flight time, on the case study route, is the airlines' advertised scheduled time, although this might be an over-estimate since it includes some buffer for delays, some of which might take place with the engines off¹⁹³. Assuming a flight time between Heathrow and CDG of 70 minutes, the flight time outside the LTO cycle, and how this time is divided between climb and descent, must be determined. Based on 8-10 minutes from take-off to cruise altitude of 25,000 ft¹⁹⁴, and about 12 minutes from this altitude to landing (Alder, 2004), descent and climb rates were estimated. Setting the maximum altitude at 25,000 ft, assuming the LTO cycle ends and starts at 3,000 ft, and based on the climb and descent rates, the climb and descent time outside the LTO cycle were calculated for the case study route. Engine power

¹⁹² And when measurements of PM₁₀ emissions are included in the ICAO data bank, and in engine certification requirements.

¹⁹³ In this case there would be no emission from the aircraft engines. Yet, emission from the Auxiliary Power Unit (APU), a small engine that supplies power to the aircraft systems when the engines are off, would take place.

¹⁹⁴ The maximum altitude an aircraft on a short haul flight is expected to reach when no ATC restrictions are imposed. In this case, the aircraft is not expected to cruise at all but to climb until required to start the descent for landing (Alder, 2004).

settings of 85% thrust for the climb and 7% thrust for the descent¹⁹⁵ stages outside the LTO cycle were assumed in order to calculate emission outside the LTO cycle (ibid).

Generally, there is no data on emissions outside the LTO cycle, and therefore the data available for the taxi and idle (7% engine thrust) and climb (85% engine thrust) stages of the LTO cycle was used. Emissions of NO_x were calculated based on the same estimates used for the LAP analysis. Since NO_x emission above ground level is considered to be much more effective in producing ozone than an equivalent amount of emission at the surface, and therefore has a higher impact on climate change, a distinction between NO_x emission during the LTO cycle (ground level emission) and during the rest of the flight was required. Emissions of CO₂ were calculated based on aircraft fuel consumption at each stage of the flight, using the ICAO engine exhaust data bank (ICAO 2002b) and a ratio of 3,150 grams of CO₂ per kg of jet kerosene consumed (DfT and HM Treasury, 2003).

Table 31: A320 flight characteristics and emissions for the case study route

Flight characteristics (time in minutes, climb rates in feet per minute)							Emission (gr/seat)	
Aircraft	Flight time	Climb rate	Descent rate	climb time	descent time	LTO time	NO _x	CO ₂
A320	70	2500	1850	8.8	11.9	49.3	188.18	42,516
A320	70	1600	1250	13.8	17.6	38.7	253.48	52,007
A320	70	3000	2800	7.3	7.9	54.8	168.83	39,704
A320	60	2500	1850	8.8	11.9	39.3	184.94	39,698
A320	85	2500	1850	8.8	11.9	64.3	193.03	46,338

Table 31 shows the base flight characteristics assumed for the case study route and the resulting NO_x and CO₂ emissions (grey cells). Given that the flight duration is 70 minutes and that the take-off (0.7 minutes), climb within the LTO cycle (2.2), climb outside the LTO cycle (8.8), descent (11.9), and approach (4.0) stages of the flight are determined means that the taxi and idle time is 42 minutes, resulting in an LTO cycle of 49.3 minutes. This is longer than the standard time, assumed for the LTO cycle, for this stage, but it is reasonable considering the level of delays on the route, and the congestion at Heathrow and CDG. Since emissions were determined mainly by the flight time assumed and the descent and climb rates for the route, a sensitivity analysis was carried out. The results are relatively sensitive to both the flight time¹⁹⁶ and the climb/descent rates assumed. The former influences the results only through a change in the idle and taxi stage of the flight when emission rates are the lowest. Changes in the climb rates lead to changes in the climb stage time, where

¹⁹⁵ Only during the last stage of the descent, the approach stage of the LTO-cycle (see section 3.4.2), the drag of the landing gear and flaps requires the engine thrust to be increased to 30% (Alder, 2004).

¹⁹⁶ 60 minutes is the fastest advertised schedule flight on the route (BAA, 2003a), and 85 minutes was used in the travel time savings analysis (see section 4.2.1).

emission rates are high since the engines are almost at full thrust. The estimates used in the sensitivity analysis, though, are probably true for only some part of the climb and descent stages, and not as an average throughout these stages of the flight¹⁹⁷. Therefore, the base flight characteristics assumed for the A320 should be considered robust enough for use.

Table 32 shows that in quantity terms NOx emissions are insignificant compared to CO₂ emissions and that while most of the NOx emissions (about two thirds) occur outside the LTO cycle where their impact is greater, CO₂ emissions are almost equally divided between emissions within and outside the LTO cycle. For both gases, the A320 flight results in less emission per seat than the B737 flight, and hence less impact on climate change.

Table 32: Emissions during the Heathrow-CDG flight for the A320 and B737 aircraft (gr/seat/route)

	NOx	CO ₂
LTO cycle	65.38	20,371
Climb + Decent	122.79	22,145
Total flight (A320)	188.18	42,516
Total flight (B737)	224.75	53,496

Tables 33 and 34 respectively are based on the same assumptions used in the LAP analysis for the egress journey and the HST journey, and to that analysis emissions of CO₂ were added. Using the car to egress the airport leads to more emissions of CO₂ than using the bus, and the TGV operation leads to less emission than the operation of trains on the WCML.

Table 33: Emissions during the egress journey (gr/seat/route¹)

Mode	NOx	CO ₂
Car (4 seats)	6.2	1,059.0
Bus (70 seats)	0.4	60.5
Total ²	4.4	749.5

¹ route: CDG-Paris city-centre, 24km.

² Modal split at CDG: 69% car, and 39% public transport (assumed to be bus service).

Source: based on CfIT (2001a).

Table 34: Emissions from the HST journey (gr/seat/route¹)

	NOx	CO ₂
TGV ²	16.8	6827.6
WCML ³	18.4	7560.0
Average	17.6	7193.8

¹ Route distance: 525km (see section 3.1).

Source: based on ²Quinet (1994), and ³CfIT (2001a).

¹⁹⁷ For a full and accurate analysis, it should be possible to estimate the exact flight profile (i.e. climb/descent rates, engine thrust, time in mode, and altitude at every moment of the flight).

Table 35 sums up NO_x and CO₂ emissions during the aircraft and the HST journeys. For both gases considered, the journey by aircraft results in more emissions and, therefore, it can be concluded that the journey by aircraft leads to more impact on climate change. However, it is not possible to estimate by how much based on measuring emission only. Furthermore, the aircraft journey impact on climate change is probably even more than might be indicated by Table 35 considering that the impact of NO_x emissions on climate change is greater at high altitude. The conclusions would not change if assuming a flight time of 60 or 85 minutes. The aircraft egress journey contribution to emission is insignificant (just over 1%), unlike its contribution to LAP.

Table 35: Comparison of emission from the aircraft and HST journeys (gr/seat/route)

	NO _x	CO ₂
Aircraft (a)	188.18	42,516
Egress journey (b)	4.4	749
Aircraft journey (a+b)	192.55	43,265
HST journey	17.6	7,194

4.3.2.2 Impact on Climate Change from the aircraft and HST journeys

NO_x emission is believed to contribute more to climate change than CO₂ emission, especially when it is emitted in the Troposphere (see section 3.4.3). Therefore, an indicator for each gas impact on climate change must be used to estimate the impact of each mode on climate change. Radiative Forcing (RF)¹⁹⁸ is the metric adopted by the IPCC to compare gases. However, the RF estimates refer to the overall global inventory of each GHG and are therefore not appropriate to measure the impact from one extra kg emission of a specific GHG. The IPCC (1999) also developed the Radiative Forcing Index (RFI), the ratio of total RF to that from CO₂ emissions alone. For aircraft, this ratio was 2.7 in 1992. This means that the total impact of aircraft emissions on climate change equals 2.7 times the impact from CO₂ emissions alone. This is a globally average estimate which also takes into account, for example, H₂O emissions, which should not be included when estimating short haul flight impact on climate change. Therefore, the RFI is also not adopted in this research. Instead, and based on the RF estimates, globally averaged RF per kg of emission, relative to one kg of CO₂, are used. Using these estimates showed that on average (and considering the 1992 situation) one kg of NO_x emissions causes 132 times the RF of one kg of CO₂ (Dings et al (2002a) based on IPCC (1999)).

¹⁹⁸ See section 2.1.2 footnote 8.

Another indicator that enables comparison between the relative impact of NOx and CO₂ emissions is the Global Warming Potential (GWP) of a gas¹⁹⁹. GWP is expressed relative to that of CO₂, which is given a GWP of unity. NOx GWP is 270 (Maddison et al, 1996). In another study, NOx GWP varies according to the time horizon considered. For 20, 100, and 500 years time horizons, NOx GWP is 275, 296, and 156 respectively (Davis and Diegel, 2002). Both Davis and Diegel (ibid) and the IPCC (1999) question the robustness of using the GWP, especially for aircraft, but the GWP is still useful in this research when acknowledging its limitations²⁰⁰.

Archer (1993) provides another estimate that can be used. He writes (no reference to the sources is given): “according to the IPCC and the UK DoE, NO₂, through its production of O₃, has on average 150-160 times the global warming effect of CO₂” (Archer, 1993: 64). Using CO₂ equivalent units to bring NOx and CO₂ emissions to a common denominator can allow a quantification of the different impacts on climate change caused by aircraft and HST journey.

Table 36: Impact of aircraft and HST operation on climate change (CO₂ equivalent units/seat/route)

1 gram of:	CO ₂	NOx	NOx	NOx	Total CO ₂ units (1 gr NOx in units of CO ₂)		
Equal CO ₂ grams	1	132 ¹	155 ²	296 ³	(132 ¹)	(155 ²)	(296 ³)
Total flight	42,516	24,839	29,167	55,700	67,355	71,683	98,216
Access/Egress	749	577	678	1,295	1,327	1,427	2,044
Total Air journey	43,265	25,417	29,845	56,995	68,682	73,111	100,260
HST journey	7,194	2,320	2,724	5,202	9,514	9,918	12,396

¹ Global averaged RF per kg of emission, relative to 1 kg of CO₂ emissions (Dings et al, 2002a).

² Average of Archer (1993) estimate of 150-160 CO₂ units for one NOx unit.

³ GWP index considering 100 years horizon (the most common time horizon used (Davis and Digel, 2002)).

Using CO₂ equivalent units shows that the aircraft journey impact on the environment is an order of magnitude greater than the HST journey impact; about 7-8 times more (Table 36). Although the results are sensitive to the conversion factor of NOx to CO₂ used, the overall conclusion and impression is not. Table 36 allow to compare the contribution of NOx

¹⁹⁹ The GWP is the immediate impact of the gas integrated over its lifetime residency in the atmosphere. The immediate impact of a gas is defined as the product of its increase in atmospheric concentrations multiplied by the increase in radiative forcing per unit of concentration (Maddison et al, 1996).

²⁰⁰ The IPCC criticism, for example, is that the GWP index does not correctly account for the impact of emission on contrails, and that the index does not consider the different impact of NOx emissions depending on location and season of emission (effects which are not considered in this research either). See IPCC (1999) section 6.2.2 for discussion on the GWP index. Davis and Diegel (2002) add that “the effects of various gases on global warming are too complex to be precisely summarised by a single number (ibid: 3-3).

emissions to climate change to the contribution of CO₂ emissions, and it shows that aircraft and HST NO_x emissions are an important element in these modes contribution to climate change. Depending on the conversion factor adopted, emission of NO_x from the flight and the egress journey might contribute more to climate change than CO₂ emission.

The above estimates, however, do not distinguish between NO_x emission at ground level and at high level. At high altitude the impact on climate change is considered to be much higher. Only one estimate was found which accounts for this difference:

According to a study made at ETSU, one gram of NO₂ has three times as potent a greenhouse effect at ground level as the same amount of CO₂, and in the upper atmosphere 335 times the effect

(Archer, 1993: 64).

Applying these to emissions from the aircraft and HST journeys, multiplying by three any gram of NO_x emitted at ground level (during the LTO cycle, the egress journey, and the HST journey) and by 335 any gram of NO_x emitted above ground level (during the rest of the flight) shows that the impact of NO_x emissions on climate change is only significant when emitted above ground level (Table 37). However, the amount and impact of aircraft NO_x emissions during flight in the Troposphere (i.e. above ground level) means that these emissions are responsible for most of the impact on climate change. Furthermore, it shows that the HST journey contribution to climate change is less than 10% of the contribution from the aircraft journey. It also shows that the contribution from the egress journey to climate change is almost insignificant. Finally, HST impact on climate change is mainly through CO₂ emissions rather than NO_x emissions.

Table 37: Impact of aircraft and HST operation on climate change (CO₂ equivalent units/seat/route)

1 gram of:	NO _x at ground level	NO _x above ground level	CO ₂
Equal grams of CO ₂ :	3	335	1
	NO_x	CO₂	Total
Aircraft LTO (a)	196	20,371	20,567
Aircraft climb+descent (b)	41,135	22,145	63,280
Total flight (a+b)	41,331	42,516	83,847
Access/Egress (c)	13	749	763
Aircraft journey (a+b+c)	41,344	43,265	84,610
HST journey	53	7,194	7,247

Source: Based on Archer (1993) estimates.

Although many studies note the different impact NOx emissions at ground level and at high altitude have on climate change, only the indicator used in Table 37 accounts for that. Therefore, it is the most relevant for use in this research. The fact that the conversion factors used in Table 36 are much lower than the one given by Archer (1993) for high level NOx emission might be the result of accounting, in a single estimate, for NOx emission at both high and ground levels. The main caveat in the estimate used in Table 37 is that it is dated.

Given the significant difference between the impact on climate change the aircraft and the HST journeys have, as presented above, the conclusions described above will not change with assumptions of flying time, aircraft type, or the assumed capacity of the car.

4.3.2.3 The cost of climate change from the aircraft and HST journeys

Many studies, as in the case of LAP, assign a monetary value to the damage caused by an increase in climate change as a result of GHG emission. Also here, the uncertainty associated with these values is evident in the wide range of values cited in the literature. While the impact on LAP from the emission of pollutants is immediate and relatively short term, the effect of emission on climate change is not immediate, and it is usually long term (e.g. more than 100 years for CO₂ emission (IPCC, 1999)). To account for future impact, but in present values, impacts that are expected in the future need to be discounted. Thus, to the scientific uncertainty associated with estimating the exact impact of each gas on climate change (which was the main cause for variance in the estimates of LAP), subjectivity is added through the decision on the discount rate used²⁰¹. This leads to even greater variance in the estimates.

The DEFRA and HM Treasury (2002) estimate the social cost of Carbon emission and conclude, based on the studies reviewed, that a marginal damage figure of £70 per tonne of Carbon (tC) (2000 prices) seems to be the one enjoying the greatest support in the literature²⁰². However, they add that “this figure is subject to significant levels of uncertainty. Furthermore, this figure excludes any consideration of the probability of ‘climate catastrophes’” (ibid: 6). Therefore, they suggest adopting an upper value of £140 per tC and a lower value of £35 per tC for sensitivity analysis. These estimates are backed by Wit et al (2003) in a report to the CfIT, and they compare with Dings et al (2002a)

²⁰¹ The differences in the discount rate used reflect “differences in political choices regarding issues of fairness between generations and between geographical regions” (Dings et al, 2002a: 43).

²⁰² This figure is consequently adopted by the UK Government when considering policies for the future of the UK aviation industry, and mainly policies concerning the expansion of airport infrastructure (e.g. DfT, 2003a; DfT and HM Treasury, 2003).

estimates²⁰³ when converted to Euro and CO₂ units²⁰⁴. Estimates from the latter are preferred for the analysis since they include estimates for the impact of NOx emission on climate change, and they are obtained from the same source used for the LAP estimates²⁰⁵. Again, the uncertainty surrounding the monetization of environmental impacts is apparent.

Table 38: Comparison of the cost of Climate Change imposed by aircraft and HST journeys (Euro/seat/route, 1999 prices)

	NOx	CO ₂	Total
Euro/kg emission	4	0.03	
Aircraft LTO (a)	0.26	0.61	0.87
Aircraft climb+descent (b)	0.49	0.66	1.16
Total flight (a+b)	0.75	1.28	2.03
Access/Egress (c)	0.02	0.02	0.04
Aircraft journey (a+b+c)	0.77	1.30	2.07
HST journey	0.07	0.22	0.29

Source: based on Dings et al (2002a) estimates.

Table 38 shows the monetary benefits, in terms of reduced climate change, from airline and railway integration. For every aircraft seat on the Heathrow to Paris route substituted with the HST seat, €1.78 damage from climate change is saved. For all the elements of the journey, CO₂ emission caused more damage than NOx emission. Emission above ground level (during the flight) is responsible for just over half of the aircraft journey's impact on climate change (€1.16).

When adopting the low cost estimates (€1.3 and €0.01 for kg of NOx and CO₂ emissions respectively) the benefit reduces to €0.59, and when using the high cost estimates (€6.6 and €0.05 for kg of NOx and CO₂ emissions respectively) the benefit increases to €2.95.

The cost estimate for NOx emissions does not distinguish between high and low level NOx emissions. Such a distinction is provided by Pearce and Pearce (2000), who estimate a shadow price per kg emission of about €0.04, €1.44, and €2.25 for CO₂, NOx low altitude, and NOx high altitude respectively. Applying these estimates yielded relatively similar results: €0.33 and €2.24 damage from the HST and aircraft journeys respectively, or €1.91 benefit per seat from airline and railway integration. However, these estimates do not seem

²⁰³ Although both Wit et al (2003) and Dings et al (2002a+b) reports were prepared by CE Delft consultancy.

²⁰⁴ 1 tonne of CO₂ equals 12/44 tonne of Carbon, or 3.67 tonnes of CO₂ equal 1 tonne of Carbon (DfT and HM Treasury, 2003; Pearce and Pearce, 2000).

²⁰⁵ It is important to note that the estimates for NOx emission used here refer to climate change impact only, while the estimates used in LAP analysis refer to the impact of NOx emission on LAP. This means that there is no double counting of damage when the impacts of LAP and climate change are aggregated.

to reflect the different impact on climate change from high and low altitude NOx emission suggested in the CO₂ equivalent analysis. To take account of this, the CO₂ cost estimate of €0.03 per kg was applied to the CO₂ equivalent units calculated in Table 37. This yielded an increase of the benefits to €2.32 per seat (€2.54 and €0.22 cost of climate change associated with aircraft and HST journeys respectively).

4.3.2.4 Potential reductions in climate change from shifting services from the aircraft to the HST – conclusions

The IPCC, undoubtedly the most authoritative research body on climate change, suggests, in its special report on aviation's contribution to climate change, that "substitution [of aircraft] by rail...could result in the reduction of carbon dioxide emissions per passenger-km" (IPCC, 1999: 12). This has been demonstrated in this research also for the Heathrow to Paris route on all the levels of analysis based on seat per route units. Furthermore, the reduction is also in NOx emissions, which in itself is very important (see below); it occurs also on short haul flights where aircraft operation is assumed not to affect climate change through water vapour emissions; and it occurs also on routes where the HST journey covers a longer distance than the aircraft journey, which is often the case (see section 3.1). Finally, the reduction in emissions is significant, more than 85% for NOx and CO₂ emissions (Table 39).

Since in both the gases measured, the journey by HST results in less emission, it can be concluded already at this level of analysis that mode substitution would lead to reduced climate change. However, in order to quantify this reduction, the relative impact of CO₂ and NOx emission on climate change must be accounted for. This was done using CO₂ equivalent units for the impact analysis, and the cost of damage from climate change for the monetary analysis. The results are summarised in Table 39.

The range of estimates, based on different methods, to convert NOx emission to equivalent CO₂ emission, and the range of monetary values for the cost of climate change available to compare between the two options of travel, suggests that the measured benefits of substitution must be considered more as an illustrative measurement. All the studies which provide the estimates emphasize the uncertainty associated with a) measuring climate change and attributing it to a certain GHG, and to a specific anthropogenic activity; b) measuring the monetary value of the damage/effect associated with climate change, and specifically for climate change impact; and c) discounting future effects to reach present value²⁰⁶. Nevertheless, the conclusion that aircraft and HST substitution would lead to reduction in

²⁰⁶ See also memorandum from Professor David Pearce to the Environmental Audit Committee for summary discussion on the valuation of climate change caused by aircraft operation (Pearce, 2003).

climate change from aircraft operation remains robust, based on the analysis and sensitivity tests.

Table 39: Climate Change impact indicators for aircraft and HST journey (in per seat per route units)

		NOx	CO ₂	Total
Emissions (gram)	Aircraft	192.55	43,265	43,458
	HST	17.57	7,194	7,211
Impact (CO ₂ equivalent)	Aircraft	41,344	43,265	84,610
	HST	53	7,194	7,247
Cost (Euro)	Aircraft	0.77	1.30	2.07
	HST	0.07	0.22	0.29

Another robust conclusion from the analysis performed is that NOx emissions from aircraft operation are a significant contributor to climate change, in some cases, depending on the estimates used, as significant as aircraft contribution to climate change through emission of CO₂. This is important to acknowledge since very often CO₂ emissions are the sole indicator of climate change impact. For example, the DfT, in its consultation on the future development of air transport in the UK, conclude that “CO₂ is considered to be the most important greenhouse gas overall and is used as the standard indicator in a wide range of transport appraisals. Our [the DfT’s] analysis therefore focuses on CO₂ emissions” (DfT, 2003a: 183). Based on the analysis above, it can be concluded that the DfT’s appraisal of the impact on climate change of runway expansion probably underestimated the impacts. One of the implications of this is that environmental tax should be higher than ‘CO₂ tax’, as it should include the impact on climate change of other emissions such as NOx.

In a subsequent document, “aviation and the environment using economic instruments” (DfT and HM Treasury, 2003), the impacts of other emissions on climate change are considered by scaling up CO₂ emissions by 2.7, according to the IPCC suggestion (IPCC, 1999). This is also adopted by the CfIT (2003). Table 39 shows that scaling up the quantity of CO₂ emissions found in this research by 2.7 to calculate the total impact from aircraft operation would lead to over-estimate of climate change impact. This is probably due to the special characteristics of short haul flights which mean that the effect on climate change is through CO₂ and NOx emission only²⁰⁷.

The uncertainty associated with aircraft operation impact on climate change through NOx emission calls for more effort towards understanding the effect of NOx emissions on climate

²⁰⁷ This research cannot establish the validity of basing the analysis on these two gases other than acknowledging that this is justified based on the literature reviewed.

change, and especially the relation between the altitude at which emission occurs and the impact. Furthermore, while it seems there is agreement in the literature that NO_x emission at the Troposphere leads to net RF (or global warming), it is not clear how much Ozone creation and subsequent increase in RF is offset by Methane creation, which leads to reduction in the RF. This is essential in order to define the real impact of NO_x emission on climate change.

The contribution to climate change from the egress journey might be considered as insignificant when compared with the flight's contribution, but it is significant (over 10% of the impact) when compared with the HST journey. Still, in terms of the efforts to reduce climate change, the main point is that benefits would come from eliminating the flight and not the egress journey when substituting an aircraft journey with a HST journey.

In the context of this research, because different effects of airline and railway integration are compared and, subsequently, aggregated, there is a tendency to prefer monetary units over other units. However, in the case of the climate change analysis the CO₂ equivalent analysis is considered more robust, as suggested in Figure 11, and should therefore be preferred (after acknowledging the uncertainties associated with this analysis as well). Furthermore, the monetary estimates of different GHG are often calculated in relation to the cost of CO₂ emission and based on a CO₂ equivalent indicator (e.g. Pearce and Pearce (2000) calculation of the shadow price of NO_x emissions at high altitude).

The overall implications of the climate change analysis for airline and railway integration are further discussed in section 4.3.4.

4.3.3 Measuring potential reductions in noise pollution from shifting services from the aircraft to the HST

Comparing aircraft and HST operations' noise impact on the case study route is similar in nature to the analysis of LAP, in that for the flight part of the journey only the LTO cycle should be considered²⁰⁸. To overcome problems of data availability, it was decided to compare noise pollution from the aircraft and the HST journey within the UK only²⁰⁹. The intention was to compare data on noise pollution from aircraft operating at Heathrow with noise pollution from HSTs operating, or expected to operate, on the CTRL. Despite the limitations of such methodologies, such as: the differences between Heathrow and CDG in

²⁰⁸ However, in the case of noise, the boundary of the LTO cycle, i.e. the height after take-off or before landing at which aircraft noise is no longer a concern or a nuisance is not known or agreed.

²⁰⁹ For the aircraft, this could be assumed as half of the impact on the route, since half of the aircraft route is within the UK. For the HST, a larger proportion of the route is in France.

terms of potential noise pollution; the differences between the UK and the French part of the HST line; the exclusion of the railway line that connects Heathrow to the CTRL; and the exclusion of the egress journey from CDG airport, to name a few, it was considered a good basis for comparison.

The study of the proposed third runway at Heathrow (DfT, 2003a) provides detailed data on noise impact from the current operation at the airport and forecasts for 2015 and 2030 in terms of area and the number of people affected by different noise levels (in L_{eq} (dBA) for 16 hour day time units²¹⁰). Based on similar data, Pearce and Pearce (2000) estimate the monetary value of the noise impact of a single aircraft movement at Heathrow. This data is sufficient to estimate the immission, impact and cost of noise from aircraft operation on the case study route in line with the methodology adopted in sections 4.3.1 and 4.3.2.

Detailed noise impact analysis was carried out as part of the planning of the CTRL in 1994 (Ashdown Environmental Ltd., 1994). This study adopts a different methodology to account for noise impact from the project. It reports the findings not in terms of the number of people (or area) exposed to different levels of noise, but in terms of the level of change in noise at different locations that were expected to be influenced by the CTRL. The criterion that used to indicate the noise impact in the study is an increase of more than 3 dB $L_{eq, 24h}$ units as a result of the CTRL. By applying this criterion, the number of dwellings along the line forecast to be affected by different levels of increase (or decrease) in noise was evaluated. The report does not provide any information on the absolute base or forecast level of noise²¹¹. Therefore, for the HST journey, it is not possible to estimate noise immission, impact and cost in a way that will allow comparison, in the context of this research, with the aircraft.

The CfIT (2001a) study provides a comparison between aircraft and HST²¹² operation noise impact similar to the one required for this research. The study applies the methods usually adopted to evaluate noise around airports to railway lines, and is therefore considered as 'best practice'. The main noise metric used in the study is based on a single journey of one aircraft or one train. For each journey, the number of people exposed to a specified value of Sound Exposure Level (SEL) and above in A-weighted decibels was calculated. This was then normalised to a value per seat based on the mix and capacity of aircraft operating on the

²¹⁰ Marked $L_{Aeq,16h}$ in Appendix D.

²¹¹ Another criterion that was used is the number of dwellings expected to be exposed to a maximum sound pressure level associated with individual events of 85 dB (Ashdown Environmental Ltd., 1994). This is an absolute figure but there is no comparable figure for aircraft events at Heathrow.

²¹² The study refers to HST, but from the services analysed (on the West and East Coast main lines) none would qualify as a true HST in this research.

analysed route. The values of SEL chosen as being indicative of typical exposure in the vicinity of railways and airports were 90 dB(A) and 100 dB(A). These values were 'free field', i.e. in the open and away from acoustically reflective surfaces. The comparison (Table 40) shows that on all the routes analysed, aircraft operation results in less noise impact than rail operation. Yet, the railway has an advantage over the aircraft on all routes except the Manchester-London route, if accepting the existence of a 'rail bonus'²¹³.

For the Manchester-London route, the analysis for the railway was repeated assuming the noise impact is affected by the screening effect of properties. A 10m high building was considered to prevent any population behind it (the shadow zone) from being exposed to any noise above the SELs of 90 dB(A). When assuming that the entire route is screened by properties, and assuming a typical level of property screening, the population exposed to noise was reduced to 18 and 90 per seat per journey respectively. Assuming typical screening for other routes would reduce the population exposed to noise by 50% (CfIT, 2001a).

Table 40: Number of people exposed to noise levels of SEL of 90 or 100 dB(A) and above per seat provided on the route

Route	Railway		Aircraft (flights to/from Heathrow)
	90 dB SEL	100 dB SEL	90 dB SEL
Edinburgh-London	57	5	11.3
Glasgow-London	86	9	8.7
Leeds/Bradford-London	85	3	20.8
Newcastle-London	49	4	6.9
Manchester-London	180	28	9.8

Source: CfIT (2001a).

The study also examined the marginal noise impact of an additional 1000 and 1040 seats for the aircraft and railway (= two additional trains) respectively. This capacity was added to the current daily services on the route. The results show that an additional 0.216 people would be exposed to noise levels of 68 dB(A) L_{den} or more per additional seat added to the railway services, and an additional 0.178 people per additional aircraft seat on the route Heathrow-Manchester (0.168 for the route Manchester-Heathrow). The results do not account for any screening effect or a 'rail bonus'. However, considering the relative increase in the number of people exposed to additional seats shows that the marginal noise burden from capacity added to the railway services is similar to the aircraft marginal noise burden (the additional

²¹³ This means that noise level of 100 dB from a train is expected to generate a response similar to a 90 dB noise level from aircraft (see section 3.4.4).

train capacity led to a 0.25% increase in the population exposed and the additional aircraft capacity to a 0.49% increase) (CfIT, 2001a).

The importance in the results described above is in showing that a robust comparison between two different modes can be made, and that aircraft operation results, on some routes, in less noise impact than railway operation. The latter contradicts findings from some other studies. For example, the European Environment Agency estimates that three million people are disturbed by train noise in Europe compared with 24 and 40 million disturbed by road traffic and air traffic respectively (CEC, 2001). Another study estimates that the noise costs of \$45,256 million for a set of 17 European countries is divided 87.3%, 7.4%, 3.1%, and 2.3% between road, aviation, freight railway, and passenger railway respectively (Brons et al, 2003). Also, in the US, the percentage of population exposed to different levels of noise from aviation is higher than the percentage of population exposed to different levels of noise from railways (EPA, 1999a). A survey carried out in England and Wales found that amongst the 1,000 dwellings that were monitored over a 24 hour period, 62.2% of the sites heard aircraft noise either at the front or rear of dwellings and only 15.2% heard railway noise. For comparison, road traffic was heard at 91.9% of the sites (DEFRA, 2001). Button (1993) compares exposure of national populations to transport noise in different countries and to different noise levels and in most, but not all, cases aircraft imposed a greater noise burden than the railway.

4.3.3.1 Measuring potential reductions in noise pollution from shifting services from the aircraft to the HST - conclusions

In the context of evaluating reduction in noise pollution from aircraft and HST substitution, the main conclusion from the studies described above is that noise burden is extremely site and route specific. “Without more detailed analysis, on a route by route basis, it is not possible to say categorically that one mode has a lower noise burden than the other” (CfIT, 2001a: 44, my emphasis).

The main differences between the case study route and the routes presented in Table 40, which are expected to influence the noise impact, include the following. To begin with, local population distribution around the airports and along the route is probably very different from the distribution of population along the Manchester-London route²¹⁴. The trains on the routes analysed are not considered to be HST, nor is the line. Thus, higher speeds, if true HST was used, would result in higher noise impact, but this might be compensated for by the high standard of the infrastructure and trains (for example, the trains on the Manchester-

²¹⁴ Although some similarities do exist.

London route are predominantly cast-iron tread-braked compared with the disc-braked which are used on all HSTs. The latter is considered to be around 8-10 dB(A) less noisy (ibid.)²¹⁵.

As a result of the above, it is not possible to conclude, nor estimate, if benefits of noise reduction can be expected from airline and railway integration on the case study route. Two distinctions between aircraft and railway operation, with respect to noise impact, should be noted, though, and these might suggest some advantage to the HST (however, this does not guarantee advantage, as was illustrated above). First, it is possible to 'protect' people from railway noise (by building barriers, trenches, tunnels, etc.), and it is almost impossible to protect people (and more so properties) from aircraft flying above. The effectiveness of such 'protection' was demonstrated on the Manchester-London railway route, and Nijland et al (2003) found that in the case of the Netherlands noise abatement measures are cost effective. In the case of the CTRL, noise mitigation measures led to a decrease in noise impact, compared with the situation before the CTRL, for 154 dwellings (Ashdown Environmental Ltd., 1994). However, abatement measures such as tunnels, which can eliminate airborne noise, might lead to groundborne noise and vibration²¹⁶.

The second important distinction between aircraft and HST operation is that although noise pollution from aircraft is usually for the LTO part of the flight and for the rail it is from the entire route, in densely populated areas, usually around airports and the train stations, noise impact from aircraft is at its highest but noise impact from the HST is usually at its lowest. For the HST, this is due to the low speeds HST run at before and after stopping (the distance required for the HST to stop means speed is reduced far from the station). This distinction is further supported by the CfIT (2001a) study that found no correlation between route distance and noise impact from train operation.

Finally, it is vital to acknowledge that if airline and railway integration does take place on the case study route, only a fraction of the aircraft traffic at Heathrow will be diverted to the HST. This suggests, due to the non-linear characteristics of noise burden and nuisance, that there might not be any noise reduction effect following airline and railway integration. This phenomenon is probably the main obstacle for evaluating the real benefits of noise reduction from aircraft and HST substitution.

²¹⁵ The CfIT, 2001a study was carried out before the introduction of the new Pendolino trains.

²¹⁶ On the CTRL, 27 km of the 109 km route (or 56% of section 2 of the route) are in tunnels (CTRL, 2004). However, it was found that "the passage of trains through the CTRL tunnels will not cause perceptible vibration impacts above the tunnels nor will it cause any damage to buildings" (CTRL, undated: 1).

4.3.4 Conclusions

Evaluating the environmental benefits from airline and railway integration on the case study route is one of the main contributions of the research. Its importance is mainly in confirming the claims in the literature that a substitution of aircraft by HST would lead to environmental benefits. These claims are confirmed for both LAP and climate change but could not be confirmed, nor refuted, with regard to noise. Furthermore, the contribution is in the in-depth analysis which allows better understanding of how these benefits occur and to estimate their magnitude. The analysis also emphasized the limitations and uncertainties associated with the evaluation of the impact of transport operation on the environment, and mainly the monetization of these impacts.

Section 3.4 began by outlining the desired methodology to evaluate the impact of transport operations on the environment. It then applied this to evaluating the impact of transport operation on LAP, climate change, and noise, specifying how this methodology should be applied to the relevant impact evaluated. It also highlighted some of the uncertainties and difficulties in doing so. These difficulties became even more apparent during the empirical analysis and were evident in the many assumptions required, and often in the lack of appropriate data. For evaluating the benefits of reduced noise, lack of data resulted in omission of this important category from the analysis. However, and despite those uncertainties and limitations, the conclusions from the environmental analysis of LAP and climate change are robust and, it is believed, they provide a realistic indication of the magnitude of benefits that can be expected from airline and railway integration on the case study route.

The rest of this section combines the findings from the LAP and climate change analysis and discusses the overall environmental benefits that can be expected following airline and railway integration on the case study route. The methodological aspects of the empirical evaluation of environmental benefits (in part common to the evaluation of other benefits) are discussed in the conclusion part (section 6.3).

Summing up the different environmental benefits is only possible when each category of benefits is quantified in monetary units. However, the nature of quantifying different elements of a policy/project, especially the environmental elements, in monetary units, and the nature of the methodology adopted, means that the monetary analysis is considered the least robust (as noted in 4.3.1, this is less true for the LAP analysis in this research). Hence, caution should be used when considering the results.

Table 41 lists the gases and pollutants included in the analysis of LAP and climate change. Table 42 summarises the cost of damage caused by these gases/pollutants in terms of LAP and climate change and the subsequent benefits from airline and railway integration; and Figure 13 illustrates the results.

Table 41: List of gases/pollutants included in the analysis of LAP and climate change

Gases/pollutants	LAP	Climate change
HC/VOC	√	X
CO	√	X
SO ₂	√	X
PM ₁₀ (Aerosols, soot)	√	X
NO _x	√	√
CO ₂	X	√
H ₂ O	X	X

The evaluation showed that, even when the HST route covers a considerably longer distance, airline and railway integration yield environmental benefits amounting to €2.17 per seat. Most of the benefits, over 80%, are the result of reduced climate change, while the remaining are from reduced LAP. However, the significance of the benefits from reduced LAP increases since these benefits would be felt locally, while climate change benefits will not necessarily be felt in either France or the UK (or in Paris and London). Furthermore, once airline and railway integration takes place, the HST services catering for the former aircraft passengers would cause more LAP than climate change damage.

The reduction in environmental pollution, following airline and railway integration, is attributed to reduction in all the gases/pollutants considered, except SO₂. Therefore, in order to increase the environmental benefits from mode substitution, efforts should be focused on reduction of SO₂ emission associated with HST operation. If this could be achieved, then it would be certain that mode substitution does result in LAP benefits.

The reduction in climate change and LAP, following mode substitution, would assist the UK Government²¹⁷ in meeting its environmental targets and international obligations to reduce GHG emission. However, it is more likely to contribute towards meeting EU standards of NO_x levels.

Summing up the LAP and climate change benefits allows to identify that the reduction in aircraft operation impact on the environment is mainly through emission of NO_x (responsible for €1.35 of damage from the aircraft), and consequently that reduction of NO_x emission contributes the most to benefits from airline and railway integration (€1.12) This

²¹⁷ As well as the French Government.

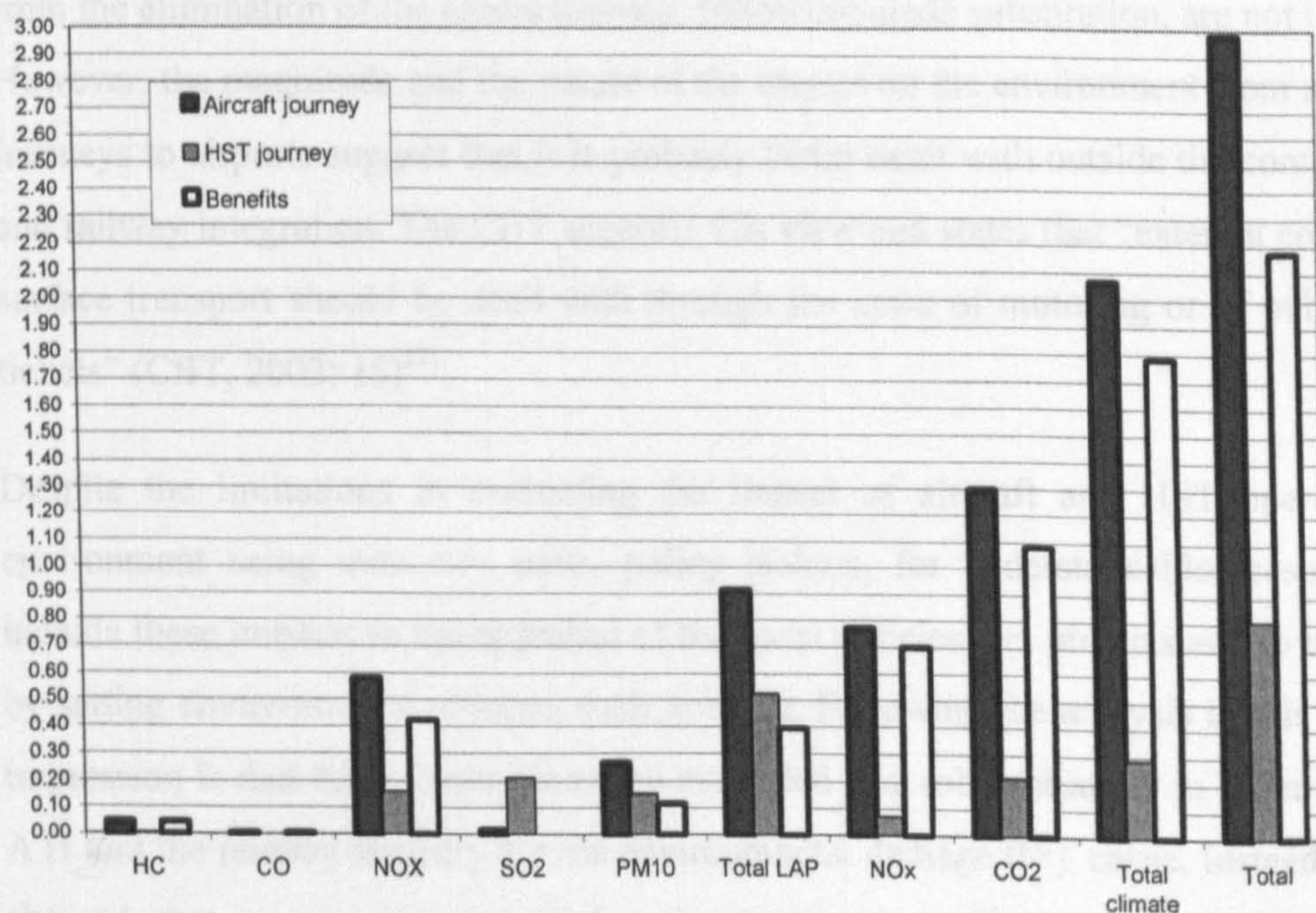
clearly indicates that attempts to reduce the impact of aircraft operation on the environment must be focused on reducing NOx emission from aircraft operation, as much as the focus is currently on reducing CO₂ emission. This is before taking into consideration the higher impact on climate change from NOx emission at high altitude²¹⁸. Despite the high uncertainties associated with the impact of aircraft NOx emission on climate change, the analysis shows that an evaluation that yields a robust indication can be made.

Table 42: Comparison of the cost of LAP and Climate Change imposed by aircraft and HST journeys (Euro¹/seat/route, 1999 prices)

Damage caused by	Local Air Pollution						Climate change			Total
	HC	CO	NOx	SO ₂	PM ₁₀	Total	NOx	CO ₂	Total	
Aircraft	0.02	0.00	0.54	0.02	0.25	0.82	0.75	1.28	2.03	2.85
Egress	0.03	0.00	0.04	0.00	0.02	0.09	0.02	0.02	0.04	0.13
Air journey	0.05	0.01	0.58	0.02	0.26	0.91	0.77	1.30	2.07	2.98
HST journey	0.00	0.00	0.16	0.21	0.15	0.52	0.07	0.22	0.29	0.81
Benefits	0.04	0.01	0.42	-0.20	0.11	0.39	0.70	1.08	1.78	2.17

¹ Rounded to the nearest cent.

Figure 13: Comparison of the cost of LAP and Climate Change imposed by aircraft and HST journeys, and the consequent benefits (Euro/seat/route, 1999 prices)



In addition to exclusion of NOx emission from the discussion on climate change, very often little or no reference is given to the impact of aircraft operation on LAP, as noted earlier (see

²¹⁸ Evaluating the monetary value of the impact of climate change using the CO₂ equivalent units would increase the environmental benefits from reduction of NOx emission to €1.66 per seat on the route.

for example: CfIT, 2003; DfT and HM Treasury, 2003; Environmental Audit Committee, 2003; RCEP, 2003²¹⁹). This is surprising given that the analysis in this research clearly indicates that enough data and knowledge exist to allow consideration of both the impact of NOx emission on climate change and the impact of aircraft operation on LAP. Furthermore, the nature of LAP impact compared to that of climate change, means that national policy makers have more control and power to influence LAP impact. Finally, this bias in the debate could lead to policies and recommendations which are not the most effective. For example, the UK Government view is that “apart from the impact of aircraft emissions on climate change, the effects tend to be local and hence are best handled at the level of each airport individually” (DfT, 2003a: 36).

The implications of focusing the debate on the impact of CO₂ emission on climate change, and the impact of NOx emission on LAP²²⁰ is an underestimation of the environmental impact from transport operation in general, and aircraft operations in particular, and recommendations for environmental charges which understate the true impact. Including PM₁₀ and SO₂ emissions is clearly important, the latter especially in the context of mode substitution.

Examining the overall benefits from airline and railway integration shows that the benefits from the elimination of the egress journey, following mode substitution, are not insignificant. However, the magnitude and the nature of the impact on the environment from access/egress journeys to airports suggest that it is probably better dealt with outside the context of airline and railway integration. The CfIT supports this view and states that “external costs related to surface transport should be dealt with through the costs of motoring or of public transport tickets” (CfIT, 2003: 15)²²¹.

Despite the limitations in evaluating the impact of aircraft and HST operation on the environment using monetary units, policy makers, for understandable reasons, strive to include these impacts in the appraisal of transport policies and projects and to mitigate them by setting environmental charges, such as taxes. Following the analysis in this research, the impression is that those costs cannot be evaluated in a robust manner in order to charge the ATI and the railway industry for the environmental damage they cause. Instead, the analysis showed that current research and understanding is sufficient to determine policy, set

²¹⁹ For example, the Environmental Audit Committee (2003) focuses on the impact of aircraft operation on climate change and ignores its impact on LAP.

²²⁰ The only pollutant considered in the LAP analysis in the UK Government consultation (DfT, 2003a).

²²¹ Nevertheless, HST services to/from airports have an important role as an access mode to airports (see section 5).

regulations, and impose taxes that will reduce this impact and influence the behaviours of both industries in a way that would account for the environmental damage they impose on society.

4.4 Benefits to airlines, passengers, and society from the operation of airline and railway integration – summary results

The Financial Analysis (FA) showed that airlines have no operating costs (OCs) incentive to adopt airline and railway integration. This, however, does not rule out the case for such integration since as long as net benefits from operating airline and railway integration exist then such integration should be adopted, at least on an operational basis. Below, the benefits to airlines, passengers and society, are summed up to determine the overall net benefits from the operation of airline and railway integration.

In line with the evaluation framework outlined in section 3.1, the benefits are first described within a MCA and then within a CBA framework in seat per route units, chosen as the appropriate unit to compare the modes on the case study route. Often, MCA is used only after monetization of all the effects within a CBA have been considered and been judged inappropriate or not robust. Here, the MCA framework is presented first since it is considered more robust, and since the MCA results are the basis for assigning monetary values to impacts/effects and thus, for the CBA.

Using the CBA and MCA results, the benefits of airline and railway integration on the case study route are put into context by calculating the benefits from shifting one year of aircraft services on the Heathrow – CDG route, to the HST. Then, airline and railway integration is evaluated at the airport level, evaluating first the potential to free runway (and ATC) capacity, and second the benefits from airline and railway integration at the airport level.

4.4.1 Benefits from airline and railway integration for every seat transferred from the aircraft to the HST

The results from the financial analysis (section 4.1), the travel time analysis (section 4.2), and the environmental analysis (section 4.3) are summarised below in seat per route units.

Using different units for different categories of expected benefits, the MCA framework, means that (dis)benefits to one group of stakeholders cannot be compared with (dis)benefits to another. Furthermore, it prevents the possibility of establishing whether, overall, operating airline and railway integration leads to net benefits (unless evidence for benefits was found

across all the evaluated categories). Nevertheless, it provides a basis for discussion on the expected benefits from airline and railway integration which is more robust than the monetary analysis that follows.

The results of the MCA (Table 43) show that not all stakeholder groups are expected to benefit from airline and railway integration. From society's perspective, however, airline and railway integration should be advocated since it leads to environmental benefits. It should also be advocated due to the benefits it would bring to the users. From a general perspective, the losses to airlines, following airline and railway integration, are of less concern, but as noted before, in a deregulated ATI it is up to the airlines to decide whether to adopt airline and railway integration, provided the infrastructure is available, and hence it is up to the airlines whether mode substitution could take place. Airlines would adopt mode substitution if they could expect to be compensated for their losses. The compensation could come through other financial benefits from airline and railway integration (some of which are discussed in 5.1.1), or from other stakeholder groups which benefit from airline and railway integration. The scope for the latter can only be evaluated by measuring benefits to passengers and society in monetary units.

Table 43: Benefits from airline and railway integration on the Heathrow-Paris route (Units/seat/route)

Category	Units	Aircraft journey (a)	HST journey (b)	Benefits (a-b)
Airline benefits				
Operating costs savings	€	26.41	29.89	No (-3.48)
Passenger benefits				
Travel time	minutes	220	205	Yes (15)
Longest segment duration	minutes	85	160	Yes (-75)
No. of interchanges	No.	2	1	Yes (1)
Environmental benefits				
Local air pollution	Toxicity	9,760	5,882	Yes (3,878)
Local air pollution	€	0.91	0.52	Yes (0.39)
Climate change	CO ₂ gram	43,265	7,194	Yes (36,071)
Climate change	NOx gram	193	18	Yes (175)
Climate change	NOx at altitude	123	0.00	Yes (123)
Climate change	CO ₂ equivalent	84,610	7,247	Yes (77,363)

Although the MCA is considered more robust than the CBA that follows, it is still based on many assumptions and depends on the quality of data available. Nevertheless, there is high confidence in the results of the financial analysis, mainly due to the data available, and in the conclusions from climate analysis due to the high difference between the modes on the

categories evaluated. Regarding the results of LAP and travel time analysis, there is less confidence and the results should be treated with caution. Although the evaluation itself yielded robust estimates, the results for the LAP analysis are not presented in terms of emissions, since such an evaluation made it impossible to conclude if integration would result in reduced LAP due to higher emission of SO₂ from the HST journey and higher emission of other pollutants from the aircraft journey. For this category, the monetary analysis, which is based on emissions, complements the toxicity analysis, and together these two measures increase the confidence in the results. For the travel time savings, the analysis depends very much on the assumptions made, and its strength is mainly in indicating that benefits could be expected and in identifying under what circumstances they are likely to occur.

Most appraisals of transportation projects are done using CBA, mainly because the results of the CBA are very easy to understand and to interpret. Furthermore, the results provide clear and unambiguous evidence of the project outcome in units that are clear to everyone. In practice, however, the CBA results might be misleading and not robust due to the uncertainty and subjectivity associated with estimating the monetary value of products, such as time saved, for which there is no market. In this research, assigning a monetary value to the benefits of environmental impact and estimated travel time savings showed the limitations of such practices. In addition, the variety of cost estimates from different studies in different countries and periods of time, which were not inflated to present prices and were converted to Euros using an illustrative exchange rate, further adds some limitations to the results. After acknowledging and accepting the limitations of using a CBA framework, it remains the best way to provide an estimate of the net benefits from operating airline and railway integration, and to put these benefits in context. A summary of the monetary benefits expected from airline and railway integration is presented in Table 44.

The results present a similar picture to the one emerged from the MCA, that airline and railway integration is beneficial for society and passengers but not for the airlines. This increases the confidence in the CBA results with regard to their conclusions (i.e. that passengers and society would benefit, but airlines would lose), although this does not make the estimate of disbenefits/benefits more correct.

Overall, the evaluation shows net benefits from the operation of airline and railway integration amounting to €26.78 per seat transferred from the aircraft to the HST on the case study route, which include €3.48 OC losses for the airlines. Passengers benefit the most from

airline and railway integration, €28.08 per seat²²² most of these benefits (87%) are enjoyed by business passengers. Society is also expected to benefit, €2.17 per seat mainly through reduction in climate change (€1.78, or 82%) but also from reduction in LAP.

Table 44: Benefits from airline and railway integration on the Heathrow-Paris route (Euro/seat/route)

	Costs per seat per route		Benefits from integration (a-b)
	Aircraft journey (a)	HST journey (b)	
Airline benefits	26.41	29.89	-3.48
Passenger benefits ¹	50.86	22.77	28.08
Environmental benefits	2.98	0.81	2.17
Total	80.25	53.47	26.78

¹ To include passenger benefit in the CBA, the VTTS per passenger was converted to VTTS per seat using an estimate of 70% LF for the aircraft and 50% LF for the HST and a passenger mix of 60% leisure and 40% business.

Net benefits from airline and railway integration mean that overall aircraft and HST substitution should take place, provided the infrastructure is in place, for the benefit of society and the users of the integrated service. It also means that the airlines can be compensated for their losses. However, the environmental benefits found are not enough to compensate for the losses from airline and railway integration, even under the high estimate of environmental benefits²²³. The financial analysis showed that only in a situation in which a kerosene tax is imposed on aircraft operations, and assuming this tax is for environmental reasons, then would environmental benefits surpass the OC losses. Internalising the environmental damage from aircraft and HST operation into the airlines and the TOCs OCs would not lead airlines to benefit from mode substitution.

Perhaps surprisingly, it is the users who could benefit the most from airline and railway integration on the case study route, €28.08 per seat. These benefits were sensitive to the assumptions on the modes' LF and the mix between business and leisure passengers, but under all the assumptions tested, these benefits were large enough to yield net benefits from mode substitution²²⁴.

²²² To compare benefits to passengers with other categories it was necessary to convert the benefits to seat units. This was done using the following estimates: 70% LF for the aircraft, 50% LF for the HST, 60% leisure passengers, and 40% business passengers (Button (2004) notes that on both side of the Atlantic, business travel accounts for somewhat over 40%).

²²³ €2.32 benefits from reduced climate change based on the CO₂ equivalent analysis (see section 4.3.2.3), and €1.07 benefits from reduced LAP when applying the 'urban' cost estimates to the aircraft and 'rural' cost estimates to the HST (see section 4.3.1.3).

²²⁴ VTTS benefits sensitivity analysis (€/seat/route): (see next page).

The benefits to passengers were also sensitive to the VOT estimates used, but under a different set of estimates (from the ones tested in section 4.2.3) the benefits would increase (see Table 22 in section 4.2.3). The limitations in the evaluation of travel time savings thus stem from the sensitivity of the savings to the assumptions. However, the monetary analysis of the travel time savings indicates that as long as airline and railway integration lead to more than two minutes travel time savings, the value of these time savings would be enough to compensate for the airlines OC losses²²⁵. Furthermore, these benefits, at least in theory, are easy for the airlines to capture through the fare mechanism (i.e. recover the OC losses through higher fares for the airline HST service, which would still leave the passengers with benefits from the reduction in travel time).

If airlines have other financial benefits from mode substitution, which would compensate for the OC losses, then airline and railway integration could be beneficial based only on the expected environmental benefits, as long as passengers did not experience travel time losses.

It is worthwhile repeating that the figures quoted above should be regarded as an indication only. Nevertheless, the evaluation showed that it is possible, and important, to incorporate travel time savings and environmental benefits in a CBA framework. There was no other way to conclude whether mode substitution would result in net benefits.

Most of the studies evaluating transport operation effects choose to use passenger units over seat units. The above analysis can be translated to passenger units to allow comparison with findings in other studies. This could be easily done by estimating a LF for the aircraft and the HST service. Using an estimate of 50% LF for the HST service, and 70% for the aircraft service, Table 45 presents the results of the CBA in passenger units. The lower HST LF, compared with the aircraft, leads to a significant reduction in the net benefits from airline and railway integration. Furthermore, if the HST LF was assumed to be 45%, or the aircraft LF was assumed to be 76% (both are realistic assumptions), airline and railway integration would result in net losses. The implications of this are discussed in section 5.

Load Factor		Mix of passengers		VOT benefits/seat
Air LF	HST LF	Leisure	Business	
70%	50%	60%	40%	28.08
75%	50%	60%	40%	31.71
65%	50%	60%	40%	24.45
70%	40%	60%	40%	32.64
70%	50%	75%	25%	19.92
65%	50%	75%	25%	17.25

²²⁵ Assuming Constant Unit Value (CUV) approach, each minute of a two minute time saving and a 15 minutes time savings is valued the same (see section 3.3).

Table 45: Benefits from airline and railway integration on the Heathrow-Paris route
(Euro/Passenger¹/route)

	Costs per seat per route		Benefits from integration (a-b)
	Aircraft journey (a)	HST journey (b)	
Airlines' benefits	37.73	59.78	-22.05
Passengers' benefits	72.65	45.55	27.10
Environmental benefits	4.26	1.62	2.64
Total			7.70

¹ HST LF 50%, aircraft LF 70%.

The analysis can also be used to show the impact of mode substitution on the city-centre to city-centre market (central London to central Paris market, where currently the HST services compete with the airlines). Assuming the distance and travel time from CDG to Paris city centre are similar for the London city centre to Heathrow journey, then to the aircraft option of travel the access journey travel time and the environmental impact of the access journey need to be added²²⁶. This would increase (and almost guarantee) travel time savings from mode substitution and would increase the environmental benefits (by €0.13 per seat, the impact from the egress journey).

4.4.1.1 The Train Operating Company increase in capacity following airline and railway integration

One of the assumptions behind the evaluation of benefits from airline and railway integration is that the TOC does not change its supply of services as a result of the capacity (demand) shifted from the aircraft. However, if the TOC adds capacity as a result of increased demand following airline and railway integration²²⁷ then the additional OCs and environmental impact associated with this increase in capacity must be accounted for.

In general, when demand for services increases it can be met through an increase in one or more of the following components: LF, vehicle capacity (size), and/or service frequency. For the case study route, vehicle capacity is fixed²²⁸. Thus, the increase in demand for HST services could be met through higher LF or higher service frequency. The former means no change in OCs and environmental impact from HST operation, the latter does. If, in addition to fixed capacity, a fixed LF is also assumed, then the increase in demand can be met only through an increase in service frequency, and it might be assumed that for every seat shifted from the aircraft, the TOC adds another seat to the HST. The effect of different capacity

²²⁶ The differences in the check-in time for the aircraft and HST services should also be accounted for.

²²⁷ The increase in demand refers to the passengers shifted from the aircraft. It does not consider induced traffic following airline and railway integration.

²²⁸ For safety reasons, Eurostar trains are operating only as fixed units with a capacity of 766 seats.

increases (measured in seats added on the HST for each seat transferred from the aircraft) on the net benefits from airline and railway integration is presented in Table 46. An increase in the HST capacity would not affect passengers' benefits, but an increase in frequency would because it could reduce the passengers' average waiting time for the HST service. However, this effect is not accounted for in Table 46 since in the travel time analysis a coordinated time-table for aircraft and HST was assumed, keeping the transfer/waiting time to a minimum.

Table 46: Benefits from airline and railway integration on the Heathrow-Paris route under different increases in the HST capacity (Euro/seat/route)

HST seats added for every aircraft seat transferred		0	0.25	0.5	0.75	1
	Aircraft (a)	HST journey (b)				
Airline benefits	26.41	29.89	37.36	44.84	52.31	59.78
Passenger benefits	50.86	22.77	22.77	22.77	22.77	22.77
Environmental benefits	2.98	0.81	1.01	1.21	1.41	1.62
Total	80.25	53.47	61.15	68.82	76.50	84.17

Table 46: (continued)

HST seats added for every aircraft seat transferred	0	0.25	0.5	0.75	1
	Benefits from integration (a-b)				
Airline benefits	-3.48	-10.95	-18.42	-25.90	-33.37
Passenger benefits	28.08	28.08	28.08	28.08	28.08
Environmental benefits	2.17	1.97	1.77	1.57	1.37
Net benefits	26.78	19.10	11.43	3.75	-3.92

Table 46 shows that within the expected range of HST capacity-increase, airline and railway integration remains beneficial, unless the TOC adds another seat for every seat transferred from the aircraft (the actual break-even point is at 0.87 added seats). However, the benefits decrease substantially as the TOC increases frequency²²⁹ due to an increase in OCs, and, but much less, due to an increase in the environmental burden.

According to Mohring's square root principle, the TOC response to the increase in demand following a shift of passengers from the aircraft would be an increase in service frequency equal to an additional 0.5 seats²³⁰. This estimate, suggested in the literature, is backed by the relatively low LF of railway services, suggesting most of the increase in demand might be absorbed through an increase in the HST service LF.

²²⁹ As noted, since the train capacity is fixed, capacity can be increased only through an increase in service frequency.

²³⁰ See Rietveld (2002) and Jansson (1980) for discussion and application of the square root principle. The use of the principle here is for illustrative purposes only.

During the 2003 summer season, the airlines offered 31 daily services from Heathrow to CDG (BAA, 2003a). Assuming the services were operated using the A320 aircraft (150 seats capacity) means that if the airlines adopted mode substitution, 4,650 daily seats would be added to the HST service (equal to around six HST services). At the same time, 14 daily HST services were operated from London to Paris (Eurostar, 2003b). Assuming the LF for the HST services was 50%, then there were 5,362 empty seats on the HST daily service, enough to accommodate the entire increase in demand shifted from the aircraft (about 3,500 passengers assuming 75% LF for the aircraft) through an increase in the HST service LF. However, at peak times it is unlikely that the an increase in demand could be accommodated through increase in the LF alone, and therefore it is expected that the frequency of HST services would increase, leading to lower net benefits than originally estimated. If the TOC added 0.5 seats for every seat shifted from the aircraft, and accounting for the current aircraft capacity on the route, then the TOC would add three daily HST services on the route²³¹.

Applying the above analysis to the MCA shows that the benefits of reduced climate change will almost not be effected by an increase in the HST service if an additional seat is added for every seat transferred from the aircraft. However, the benefits in terms of toxicity factors are sensitive to the capacity added by the TOC, the break even point being at 0.65 added seats.

4.4.2 Benefits from one year operation of airline and railway integration on the Heathrow - Paris route

To put the above results in context, the benefits from a one year operation of airline and railway integration on the Heathrow-Paris route were evaluated. During 2003, 20,353 flights were recorded on the route (CODA, 2004), which translates into 3,052,950 seats (assuming 150 seats per flight). Tables 47 and 48 translate the results of the MCA and CBA to annual benefits from mode substitution on the route.

The time saved as a result of airline and railway integration is equal to 31,802 days. The fact that the HST journey allow longer uninterrupted journey time, and assuming that this allows unproductive time to be converted into more productive time (if conditions on board the HST allow more productive use of travel time) then more than 159,000 days of productive time are gained. The scale of the environmental benefits is manifested in Table 47 in the form of more than a 110,000 tonne reduction in CO₂ and 534 tonnes of NO_x emission (375 tonnes of which is saved from the upper atmosphere). In CO₂ equivalent units, this equals

²³¹ $4650 * 0.5 / 766 = 3.03$.

more than 200,000 tonnes. However, for airlines the yearly OC losses amount to €10.62m, the significance of which increases due to the ATI's financial crisis during 2003²³².

Table 47: Benefits from airline and railway integration from one year of operation, MCA¹

Category	Aircraft journey	HST journey	Benefits
Airline benefits			
Operating costs savings (millions €)	80.64	91.26	-10.62
Passenger benefits			
Travel time (days)	466,423	434,621	31,802
Longest segment duration (days)	180,209	339,217	-159,008
Environmental benefits			
Air pollution (Toxicity units, millions)	29,798	17,957	11,841
Climate change (Tonne CO ₂)	132,087	21,962	110,125
Climate change (Tonne NO _x)	588	54	534
Climate change (Tonne NO _x at altitude)	375	0	375
Climate change (Tonne CO ₂ equivalent)	258,309	22,123	236,186

¹ Based on 20,353 flights between Heathrow and CDG during 2003 (CODA, 2004).

Table 48: Benefits from airline and railway integration from one year of operation on the Heathrow-Paris route, CBA (2003, million €/seat/route)¹

	Costs per one year operation		Benefits from integration (a-b)
	Aircraft journey (a)	HST journey (b)	
Airline benefits	80.64	91.26	-10.62
Passenger benefits ²	155.26	69.53	85.73
Environmental benefits	9.10	2.47	6.64
Total	245.00	163.25	81.75

¹ Based on 20,353 flights between Heathrow and CDG during 2003 (CODA, 2004).

² To include passenger benefit in the CBA, the VTTS per passenger was converted to VTTS per seat.

The net monetary benefits from one year of airline and railway integration on the route amount to €81.75 millions (Table 48). If the TOC adds 0.5 seats for each seat transferred from the aircraft, then the net benefits decrease to €34.89 million. Not necessarily all the airlines which operate services between Heathrow and CDG would adopt mode substitution. BA, which uses some form of H&S at Heathrow is the most likely airline to adopt mode substitution at Heathrow²³³. During summer 2003, BA operated 11 out of the daily 31 flights from Heathrow to CDG, about 35% (BAA, 2003a). 35% of the estimated 2003 net benefits

²³² Attributed to the fall in demand due to the economic downturn, the war in Iraq, and the SARS outbreak (see section 2.1).

²³³ AF is more likely to adopt mode substitution because it is already doing so on some routes, but this is based at CDG and not at Heathrow airport. Another advantage AF has over BA, in terms of mode substitution, is that CDG already has a HST line and station in operation.

amounts to €28.61 million, still a considerable level of benefits, but it also entails €3.27 million OC losses for BA, certainly not an incentive for mode substitution.

4.4.3 Airline and railway integration at the airport level – the scope for benefits and the potential to alleviate congestion at Heathrow

The benefits from airline and railway integration at Heathrow are not limited to the case study route. Several other routes are suitable for airline and railway integration and they must be accounted for to estimate, at the airport level, the overall benefits. In addition, while airlines can decide whether to adopt mode substitution on a route basis (as long as the infrastructure to do so is provided), policy makers and airport operators can only decide whether to provide the infrastructure on an airport basis.

One of the reasons for airline and railway integration is its potential to relieve congestion at airports. By evaluating the routes suitable for aircraft and HST substitution at Heathrow, the potential to relieve congestion is evaluated as well. This is described first.

4.4.3.1 The scope to free runway capacity at Heathrow through airline and railway integration

The criteria for aircraft and HST substitution is usually based on route distance, and there seems to be general agreement that the HST ceases to be a competitive substitute to the aircraft on distances greater than 1,000 km (see Appendix B and section 2.3). Based on this assumption and on the routes currently served from Heathrow (BAA, 2004), the routes considered suitable for aircraft and HST substitution are listed in Table 49. To estimate the aircraft route distance, 10% was added to the great circle distance between Heathrow and the destination airport. To estimate the HST route distance, the road distance from London to the destination city was used based on the likely route of the HST according to the proposed EU HST network (UIC, 2003)²³⁴. The ratio between the aircraft and the HST route was then calculated. Considering the great circle distance, all routes in Table 49 seemed good candidates for mode substitution, certainly the ones up to 800km, which include all the routes from Leeds/Bradford to Zürich. However, when taking into account the HST route distance, then the routes to Hanover, Hamburg, Geneva, Stuttgart, Lyon and Zürich do not seem to be good candidates for mode substitution anymore. Within the remaining routes, the ratio between the aircraft and the HST route distance can provide an indication for additional routes on which substitution might not be worthwhile, although the HST route distance is

²³⁴ See Figure B2 in Appendix B.

within the range considered favourable for substitution. Thus, the routes to Leeds/Bradford, Manchester, Paris, and certainly Amsterdam stand out.

Table 49: Routes from Heathrow suitable for consideration of aircraft and HST substitution (based on route distance)

	Great circle distance (km) ¹	Aircraft route (km) ²	HST route (km) ³	Distance ratio (HST/aircraft)
1. Leeds/ Bradford	227.4	250	313	1.25
2. Manchester	242	266	321	1.21
3. Paris	347.7	382	510	1.33
4. Brussels	350.3	385	398	1.03
5. Amsterdam	369.9	407	612	1.50
6. Newcastle	404	444	446	1.00
7. Düsseldorf	500.9	551	650	1.18
8. Edinburgh	532.5	586	641	1.09
9. Cologne	533.9	587	610	1.04
10. Glasgow	553.7	609	648	1.06
11. Aberdeen	646.2	711	832	1.17
12. Frankfurt	654.4	720	802	1.11
13. Hanover	702.5	773	904	1.17
14. Hamburg	744.6	819	1063	1.30
15. Geneva	754.2	830	1051	1.27
16. Stuttgart	756	832	1006	1.21
17. Lyon	757.4	833	974	1.17
18. Zürich	788.3	867	1204	1.39
19. Bilbao	927	1,020	1425	1.40
20. Munich	941.2	1,035	1229	1.19
21. Berlin	961	1,057	1187	1.12
22. Nice	1040.3	1,144	1493	1.30
23. Barcelona	1147.7	1,262	1633	1.29

¹ Source: Landings.com, 2003.

² Great circle distance plus 10%.

³ Source: Route Planner (2004) based on the forecasted European High speed Network (UIC, 2003).

In the context of aircraft and HST substitution, route distance is used as an indicator for travel time savings, the common criterion for mode substitution. Based on the framework to evaluate travel time savings on the case study route (Table 20 in section 4.2), travel time is calculated for each mode on the remaining routes considered suitable for airline and railway integration. For the airlines, to the advertised flight time²³⁵ 60 minutes of transfer time between the aircraft and the egress journey and 20 minutes egress journey were added. The

²³⁵ Different flights on the same routes have different scheduled times depending on expected level of congestion at different airports and at different times of the day. The flight time presented in Table 50 is the most common low flight time (i.e. not necessarily the fastest advertised time).

HST journey time was calculated by assuming an average speed of 200 kph, for a good HST service, and 250 kph for an outstanding HST service²³⁶, and multiplying by the route distance. The assumption is that the transfer time at Heathrow between the incoming flight and the outgoing flight or the HST service is similar. The travel time analysis (Table 50) shows that there is a case for airline and railway integration on the routes from Heathrow to: Leeds/Bradford, Manchester, Brussels, and Newcastle when the HST average speed is 200 kph, and probably even lower. On the routes to Aberdeen and Frankfurt there seems to be no scope for mode substitution even if high average speeds are achieved. On the remaining routes, to Paris, Amsterdam, Edinburgh, Cologne, Glasgow, and Düsseldorf, the scope for mode substitution depends on the level of HST service in terms of speed. From these routes, the route to Paris stands out as the most likely to have scope for airline and railway integration. This was also shown in the detailed travel time analysis for this route. The average speed assumed for the Heathrow-Paris HST journey in the analysis in section 4.2 was 197 kph²³⁷. In section 4.2, the HST advantage was also based on a 15 minutes faster transfer time at Heathrow for the HST service. If this is applied to the routes to Amsterdam, Edinburgh, Cologne, Glasgow, and Düsseldorf, then there might be scope for airline and railway integration on these routes as well.

Table 50: Routes from Heathrow suitable for consideration of aircraft and HST substitution (based on travel time, minutes)

	Flight time	Journey time ¹	HST time (avg. speed)		Adv. HST	
			200 kph	250 kph	200	250
1. Leeds Bradford	55	135	94	75	41	60
2. Manchester	60	140	96	77	44	63
3. Paris	65	145	153	122	(-8)	23
4. Brussels	70	150	119	96	31	54
5. Amsterdam	70	150	184	147	(-34)	3
6. Newcastle	65	145	134	107	11	38
7. Düsseldorf	75	155	195	156	(-40)	(-1)
8. Edinburgh	75	155	192	154	(-37)	1
9. Cologne	75	155	183	146	(-28)	9
10. Glasgow	80	160	194	156	(-34)	4
11. Aberdeen	85	165	250	200	(-85)	(-35)
12. Frankfurt	95	175	241	192	(-66)	(-17)

¹ Flight time plus 20 minutes egress journey, plus 60 minutes transfer time between flight and egress journey.

²³⁶ The benchmark for average travel speed can be the TGV Méditerranée line. According to the time table, a journey from Paris to Marseille (750 km) will be running at 250 kph (Perren, 2001). For comparison, current average speed between London and Paris (495 km) is about 165 kph, but will increase to around 220 kph once the CTRL is completed.

²³⁷ This includes an average speed of 220 kph for the London-Paris section, and an average speed of 72 kph for the London-Heathrow section (30 km in 25 minutes).

The benefits from airline and railway integration at the airport level, and the potential to alleviate congestion, depend on the present level of service on each route considered for mode substitution. Using the airline schedules for summer 2004 (Innovata, 2004), the number of services on these routes was calculated based on the number of one-way services from Heathrow on a Wednesday²³⁸. The number of yearly ATMs, or slots, at Heathrow and the share they represent of Heathrow's total runway capacity, which in 2002 was 466,459 (CODA, 2003)²³⁹, is shown in Table 51.

Table 51: The scope to alleviate congestion at Heathrow through airline and railway integration (routes ranked by travel time advantage according to Table 50)

	Daily services (one way) ¹			Yearly services (two way)		
	Total	By BA	By bmi	ATM	% of LHR ²	Accum.
1. Manchester	15	8	7	10,920	2.3%	2.3%
2. Leeds/Bradford	4	--	4	2,912	0.6%	3.0%
3. Brussels	13	6	7	9,464	2.0%	5.0%
4. Newcastle	4	4	--	2,912	0.6%	5.6%
5. Paris	27 ⁽³⁾	9	5	19,656	4.2%	9.8%
6. Cologne	6	3	3	4,368	0.9%	10.8%
7. Glasgow	18	10	8	13,104	2.8%	13.6%
8. Amsterdam	23 ⁽³⁾	6	8	16,744	3.6%	17.2%
9. Edinburgh	16	8	8	11,648	2.5%	19.7%
10. Düsseldorf	9	4	5	6,552	1.2%	20.9%
Total	135	58	55	98,280		20.9%

¹ Source: Innovata (2004).

² Based on 466,459 ATMs in 2002 (CODA, 2003).

³ The other services are by AF on the route to Paris, and KLM on the route to Amsterdam.

Table 51 shows that if on all routes airline and railway integration would have taken place, over 20% of Heathrow's capacity would be freed. Heathrow was the world's third largest airport in 2002 (ACI, 2004). Considering the routes which show a high potential for mode substitution based on travel time analysis (route 1-5 in Table 51), then almost 10% of Heathrow's capacity would be freed²⁴⁰.

At Heathrow, BA and, to a lesser extent, bmi through its alliance with LH and other Star alliance airlines, operate some form of H&S strategy, and these are the airlines which are likely to adopt integration. BA's level of service on the routes found suitable for mode

²³⁸ Then, the daily number of services was multiplied by 364 days of the year, and then by two to account for the return journey as well. Wednesday is considered to represent an average level of service throughout the week. It is expected that the level of service will be lower at the weekend and higher at the start and end of the working week.

²³⁹ CODA (2004) analysis of delays in 2003 does not include analysis of traffic by airport.

²⁴⁰ This matches the estimates by Sharp (2002), Caves and Gosling (1999), and Buchanan and Partners (1995). See section 2.3.4.

substitution amounts to 8.9% of Heathrow's runway capacity in 2002 (4.2% on routes 1-5 in Table 51). Most of the freed capacity would come from mode substitution on the routes to Glasgow (1.6% of Heathrow's capacity), Paris (1.4%), Manchester (1.2%), and Edinburgh (1.2%).

In the light of the forecast growth in demand for air service, the potential to free capacity at airports through mode substitution might seem insignificant. However, whether this demand is met or not (or should be met) is not relevant for the core discussion on airline and railway integration. The percentages of Heathrow's capacity mentioned above are indeed significant²⁴¹.

4.4.3.2 Benefits from airline and railway integration at Heathrow airport

Airlines' short haul routes, which are currently served by aircraft and were found suitable for mode substitution, share relatively similar characteristics, especially in terms of the route distance and travel time. Therefore, the evaluation of benefits from airline and railway integration on the case study route can indicate whether benefits can be expected on other routes as well. However, the differences that do exist between the routes, mainly the HST route distance in comparison with the aircraft route (but also other differences such as the type of aircraft used, the HST journey average speed, landing charges, etc.), means that the estimates should not be directly applied to other routes but just used as an indication for potential benefits from airline and railway integration.

The financial analysis revealed that operating HSTs result in lower OCs per seat-km than operating aircraft and therefore, when the aircraft and HST routes are of similar distance, airlines can expect OC savings from airline and railway integration. The ratio between the aircraft and HST OCs per seat-km found was 1.21. Thus, on six out of the 10 routes where mode substitution could lead to travel time savings (Table 51), airlines can expect OC benefits from mode substitution and these benefits might shift the weight towards mode substitution even if the potential for travel time savings is not large. Out of the five routes on which there is high certainty for travel time savings, only on the routes to Brussels and Newcastle are OC savings likely.

The clear advantage of the HST over the aircraft in terms of impact on climate change means that on all the routes in Table 49 airline and railway integration would lead to a reduction in the impact on climate change from aircraft operation. However, the value of this reduction, as measured on the case study route, indicates that it would not be enough to justify airline

²⁴¹ This issue is further discussed in section 5.

and railway integration on routes where travel time savings are not expected. The impact of aircraft operation on LAP, unlike the impact on climate change, is independent of the flight distance, and therefore the aircraft operation impact on LAP calculated in section 4.3.1 could be applied to all the routes considered above. The impact of HST operation on LAP depends on the route distance, and the analysis in section 4.3.1 shows that the HST loses its advantage over the aircraft, when LAP is measured in toxicity units, on routes longer than 870 km, the corresponding route distance for the monetary units is 920 km. This means that on all the routes in Table 50, benefits of reduced LAP can be expected as a result of airline and railway integration.

The value of the travel time savings found on the case study route indicates that this category of benefits is the main factor which determines if net benefits from airline and railway integration can be expected. This holds as long as the CBA in this research is accepted. Considering the MCA, it can be concluded that on routes where travel time savings are expected and the ratio between the HST and the aircraft route distance is lower than 1.21, benefits to all stakeholder groups are expected from airline and railway integration. These routes include the routes from Heathrow to Brussels, and Newcastle. In the context of this research, it is not possible to infer if the lower number of transfers required and the longer uninterrupted journey time, when travelling by HST, can compensate for longer travel time on board this mode.

Following the above, criteria for mode substitution can be defined. **On HST routes of under 800 km in length, where the HST route is not more than 20% longer than the aircraft route, and the average HST speed along the route is at least 200 kph, aircraft and HST substitution under airline and railway integration is beneficial to airlines, passengers, and society.** This definition is more robust than the ones usually cited in the literature based on route (aerial) distance. However, the analysis above also suggests that, overall, operating airline and railway integration depends on whether travel time benefits could be achieved, and this is a more appropriate criterion.

One of the benefits of the model for mode substitution defined in this research is that the criteria for airline and railway integration are almost independent of the demand for air services on the route. The reason is that the justification for the HST service is the demand from the city-centre to city-centre route, i.e. the London-Paris HST route, and not the demand at the airport. In that sense, it is enough that demand at the airport would justify the extension of the HST service from London to Heathrow²⁴². It is important to note, however,

²⁴² On the Frankfurt-Stuttgart route, however, the HST service passes through Frankfurt airport so, there is virtually no extension or detour in order for the HST service to cater for LH's passengers,

that the analysis compares the modes based on the entire Heathrow-Paris HST route and not just the London-Heathrow part of it²⁴³.

IATA (2003) analysed the potential for airline and railway integration (as defined in this research) on intra-European routes and the first criterion used for selecting such routes was a demand of more than 300,000 seats per annum (equivalent to three daily return services by B737). The characteristics of Heathrow means that short haul routes with less demand would probably not be served from Heathrow, but at other airports, routes suitable for airline and railway integration would have been excluded from IATA's analysis. The second criterion used by IATA was air distance of less than 850 km, which in this research was identified as less appropriate than the HST route distance. IATA (ibid) identified four routes from London with high potential for airline and railway integration, including the routes from London to Brussels, Cologne, Düsseldorf, and Paris; two routes with future potential (where HST between the cities is expected by 2005), including the routes to Amsterdam and Frankfurt; 8 routes where undeveloped potential for air/rail services exist but no HST is currently planned between the cities. This category includes the routes to Aberdeen, Edinburgh, Glasgow, Geneva, Hamburg, Manchester, Newcastle, and Zürich; and finally one route, to Stuttgart, was identified as having low potential for air/rail services (due to lack of HST between the cities and a market size smaller than 700,000 seats per annum). Clearly, if IATA's exercise was repeated using the criteria defined in this research, then different results would have emerged.

In addition to OC savings, travel time savings and environmental benefits, airline and railway integration would lead to other benefits, many of them result from the runway capacity released through mode substitution. Table 51 suggests that such benefits are expected to be significant. These, however, are categorized as indirect benefits and are not directly associated with the operation of airline and railway integration. They are therefore discussed separately in section 5.

4.4.4 Conclusions

Soon after the inauguration of the modern HST, it became apparent that HST can substitute the aircraft on some routes. Years later, the immense growth of the ATI industry, and forecasts for continuous rapid growth in demand for air services, led to increased support for the idea of mode substitution as a solution to the congestion faced by the ATI. The idea also

suggesting the decision whether the HST should serve the airport is almost independent of the demand from the airport.

²⁴³ Only this way comparison of like with like between the modes can be insured.

gained many proponents in the light of increasing concerns about the ATI's impact on the environment. Under these conditions, it was recognised that, for real mode substitution to take place, i.e. an existing flight is substituted by an existing HST service, instead of a HST service being added to the flight service and the two competing against each other, the airlines should initiate and support mode substitution. This led to the development of the airline and railway integration model for mode substitution. In order to allow airlines to substitute the aircraft with HST, the model requires the airport to be connected to the HST network. It was also necessary for the airline to integrate its HST services with its network of air services.

The connection of an airport to the HST network can provide many different benefits and have many different effects on different stakeholders in and outside the ATI, plus in itself it is a major and costly project. Some of these benefits are not related to mode substitution, others are indirectly related, while some have counter effects. For example, if the freed capacity following mode substitution is used to add long haul aircraft services, there would not be, overall, environmental benefits. Therefore, and in order to evaluate the direct effect of mode substitution, the research has focused on the operation of airline and railway integration. The aim was to identify, and quantify, the direct effect on airlines, to examine if they have an incentive to adopt mode substitution, on passengers, those who are expected to be shifted from the aircraft to the HST, and society, which expects environmental benefits. The focus on the operation of airline and railway integration was also due to the methodological challenges in empirically measuring such benefits, and the level of analysis required in order to make a valuable contribution to the discourse on aircraft and HST substitution.

Since different types of benefits to different groups of stakeholders are expected, measuring the benefits in monetary units was crucial. This was also necessary to allow a comparison of the benefits with the cost of connecting the airport to the HST network. Thus, a CBA framework was adopted as the main evaluation tool. However, the nature of quantifying different effects in monetary units required these effects to be quantified first in other units²⁴⁴ using a MCA framework. In addition, the limitations in, and challenges of, measuring travel time savings and environmental effects in monetary units required the adoption of a MCA framework to support the CBA findings.

Beside the methodological challenge, the empirical analysis depended on the availability of data and the ability to effectively use data from different studies in this research. Other than

²⁴⁴ The exception being the financial benefits.

in the evaluation of reduction in noise pollution, the quality of the results and the level of contribution were hardly affected by issues related to the quality and availability of data. In most cases, the data available allow valuable results and robust conclusions to be reached. The limitations of the analysis were due more to the level of understanding currently achieved on matters related to this research (such as the level of understanding on how aircraft operation impact climate change), the scope of this research (e.g. not using the exact flight profile to estimate CO₂ emissions), and methodological issues (e.g. the application of VTTS estimates to the time savings found on the case study). The methodological conclusions following the empirical analysis in this research, and the affect of the data available on the results, is further discussed in the conclusions (section 6.2).

The conclusions that can be drawn for other airports and routes from operating airline and railway integration on the Heathrow-Paris route, based on the main findings summarised above, are as follows. The OCs per seat-km values found for the aircraft and the HST can be used for any route to find if OC savings would be achieved by airlines. The route-specific variables (e.g. landing charges) in the aircraft OC estimates are not expected to be significantly different on other routes. Benefits to passengers were found to be the most important category of benefits, and in addition probably the most sensitive to the general assumptions used, and to the specific route conditions. Therefore, a specific analysis, based on the framework suggested here, should be carried out for each route. If travel time savings are likely, then these can be expected to be the main benefits. In different circumstances, e.g. when the proposed route is a domestic and not an international route, the application of the VTTS might be easier, and should be based on the estimates used in the country within which the route passes. Nevertheless, the multi-modal obstacles in applying the VTTS estimates will remain. Regarding the environmental impact, it can be expected that on all routes where airline and railway integration seems plausible, environmental benefits would occur. Their extent (also in monetary value) could probably be predicted based on the results found in this research.

For airports other than Heathrow, the same evaluation that was carried out above (section 4.4.3) could be repeated in order to identify the routes on which airline and railway integration could take place, and to estimate the potential to free capacity. Since not all airlines operating on a route suitable for mode substitution are likely to adopt it, the level of benefits at the airport level depends very much on how much the airport is dominated by one airline and the extent to which this airline operates a H&S network. As a general indicator of the potential from airline and railway integration at a specific airport, the routes from the airports could be analysed according to the definition for mode substitution given above.

After the analysis of operating airline and railway integration was completed, the assumption that the airport is connected to the HST network could be relaxed and the concept of mode substitution re-examined in a wider context which also considers indirect benefits. At an airport level, this wider context must be accounted for to estimate the desirability of airline and railway integration. For airlines, the operation context of mode substitution might be enough if the infrastructure is available. Section 5 examines airline and railway integration in a wider context.

5. Airline and railway integration in a wider perspective

The main empirical part of the research (section 4) evaluated direct benefits to the main stakeholders from the operation of airline and railway integration, but this evaluation considered only part of the expected effects/benefits from airline and railway integration. A complete evaluation of airline and railway integration must adopt a wider perspective. This is done in this section by presenting and discussing the most relevant, in the context of the research, issues in airline and railway integration that have not been dealt with so far.

The section begins by discussing and presenting additional benefits, on top of the benefits identified in section 4, from airline and railway integration to the airlines, airports, and the railways, the operators/private sector beneficiaries (section 5.1). Next, airline and railway integration is examined in transport policy context examining the benefits to the wider population (section 5.2). It is assumed that the debate on air transport policy, from government perspective, reflects the interest of society and passengers. Then, practical elements in airline and railway integration are examined (section 5.3) including: the investment required to begin operation of airline and railway integration, the possible agreements between the airline and the TOC, and the physical and cultural elements in the integration between the rail and air industries. Section 5.3 ends by focussing the discussion back on the ATI examining the future of the H&S strategy, which is an important element in airline and railway integration, and how HST services would fit into airlines' operation.

The context of the discussion is different from the one in which the direct benefits were evaluated in several ways. First, it is recognised that if investments in a HST connection to Heathrow would be made then the benefits would also come from improved access to the airport, and these benefits must be considered as well, as they are directly related to the investments in airline and railway integration even if not directly to its operation. Second, the HST station envisaged for Heathrow should include access to conventional services and should be a 'through' station that would allow services from the airport to the North and West and not only to the South-East towards the CTRL. This would also lead to benefits

directly related to the investments in airline and railway integration that need to be accounted for. Third, airline and railway integration would also refer to using the train as a continuation to the flight on routes where the train does not substitute the aircraft (the Finnair example in section 2.3.3, in which the airline uses train services to extend its network). Finally, as indicated earlier, airline and railway integration can replace the need for a new runway at Heathrow and this is another element governing the discussion in this section.

The empirical nature of this research means that the discussion focuses on the UK side of the case study route and mainly on Heathrow since this is where the impedance to airline and railway integration exists. The discussion on the wider perspective of airline and railway integration keeps in mind the benefits from the operation of airline and railway integration.

5.1 Additional benefits from airline and railway integration

Section 4 evaluated the benefits of operating airline and railway integration. These benefits, however, are not the only benefits expected. Additional benefits stem either from the provision of high quality railway and HST access to Heathrow or from benefits from airline and railway integration which are not directly related to its operation.

The additional benefits from airline and railway integration, also referred to as the indirect benefits, were not quantified but only discussed. Some of these benefits are ‘enjoyed’ by more than one group of stakeholders but for the discussion they were allocated to one group.

5.1.1 Additional benefits to airlines from airline and railway integration

It is mainly up to the airlines to determine if airline and railway integration takes place and therefore its effect on the airlines is emphasized in the research. The OC analysis showed that, on the case study route, airlines would lose from integration and therefore have no incentive to adopt it unless they can expect other benefits. Such benefits are discussed below. The main additional benefits to airlines can be separated between benefits associated directly with the freed slots and network benefits. The latter has more of a strategic importance.

Airlines are assumed to benefit from any expansion of airports. At congested airports, the number of slots available for an airline will determine its scale of operation from that airport, which makes a slot, especially at airports like Heathrow, a valuable asset. Currently, the lack of capacity at Heathrow is manifested through the lack of slots. A slot has no market price since it is given for free to the airlines and airlines are forbidden to sell or buy it from other airlines²⁴⁵. Nevertheless, the shadow price of a slot can be estimated.

“Britain’s national carrier has a market value of £3.2bn [€4.8] but it also owns 40 per cent of the landing and take-off slots at Heathrow, which could be worth up to £2.5bn [€3.75]” (The Observer, 2004). Considering this estimate, the slots currently used by BA for the services to CDG alone are worth over €130 million. Furthermore, a deal in which BA got two of the

²⁴⁵ Currently, airlines have a “grandfather” right to slots they have flown in the previous season. Any slots they did not use for 80 percent or more in the previous season they must give back. The inefficiencies associated with, and the anti-competitive nature of, the current system of slot allocation have led to pressure to introduce a new market-based system or at least allow airlines to trade in slots (see NERA, 2004). In the UK, support for this approach comes from the DETR (2000a), DfT (2003b), House of Commons Transport Committee (2003), Environmental Audit Committee (2003), and CfIT (2003) amongst others.

peak time slot pairs at Heathrow from United Airlines, in exchange for two other pairs of slots²⁴⁶, was estimated to be worth €15 million (Airline Business, 2003). It can be estimated based on the above that the value of the freed slots alone would be enough to compensate for the OC losses. In addition to the opportunity cost arising from freeing up slots, these slots can be used to add more services on routes not suitable for mode substitution, leading to an increase in revenues and profits, especially if long haul services replace short haul services²⁴⁷. In this respect, the estimated value of slots represents their opportunity profit. Furthermore, airline and railway integration would lead to freeing up aircraft for use on other routes eliminating, or at least delaying, the need to purchase new aircraft²⁴⁸.

Airlines operating from congested airports cannot expand their services and add routes to their network. Airline and railway integration, however, offers an alternative to the runway and allows airlines to expand their network and services even at congested airports. This holds for any airline, but is of much more importance for airlines operating a network of services rather than a collection of point-to-point services with no direct connection between them. Hence, airline and railway integration allows airlines to increase the number of destinations in their network by offering rail (/HST) services to destinations not served before due to lack of capacity. In the UK, for example, there are no services from Blackpool, Liverpool, and Cardiff to Heathrow leading passengers to use other European airlines and airports for their long haul journeys instead of using (British) airlines based at Heathrow.

For BA, the lack of capacity at Heathrow meant that it had to scale down its H&S operation by either shifting some services to Gatwick or withdrawing from some routes and, instead, concentrating on long-haul routes mainly across the Atlantic²⁴⁹; in the mean time LH and AF are moving in the opposite direction and emphasizing their H&S operation (Doganis, 2002b). Lack of capacity also meant that BA could not schedule ‘waves’ of incoming and outgoing flights next to each other, which is one of the main elements of H&S operation, to allow passengers a range of connecting opportunities at the hub airport in a relatively short time. “Air France schedules 52 departures in 55 min at CDG, KLM 63 departures in 75 min at AMS and Lufthansa 68 departures in 105 min at FRA. In contrast BA schedules about 18 departures in every hour at Heathrow” (Doganis, 2002b: 2). HST services at Heathrow, like

²⁴⁶ Because it is illegal to trade in slots, BA had to give United Airlines two slots in return (which it will probably not use), officially making it a swap of, and not trade in, slots.

²⁴⁷ Long haul routes are considered to be more profitable. Furthermore there is a view, supported by general analysis of European carrier results over the last decade, that “airlines lose money on short-haul flights” (IATA, 2003: 92). See also López-Pita (2003 and Doganis (2002b).

²⁴⁸ In contrast, airline and railway integration might require the purchase of new HSTs, offsetting the gains from freeing aircraft. Under airline and railway integration the airlines, directly or indirectly, are expected to contribute towards the costs of new HSTs.

²⁴⁹ However, these changes are also associated with changes in the market and changes in demand BA had to face.

the services at Frankfurt, would allow BA to substantially increase its hourly departures at Heathrow. Yet, a prerequisite for that is, as outlined earlier, a fully integrated railway service and a Minimum Connecting Time of 45 minutes for transfer between a flight and a rail service.

The lack of capacity, and consequently the obstacles in operating a H&S system, makes it harder for BA to compete against its main rivals AF, KLM, and LH²⁵⁰ (see Doganis, 2002b), and likewise for any airline based at Heathrow. The concentration of BA on the long haul (trans-Atlantic) routes comes at the expense of serving the local market which in turn is captured by airlines such as KLM which enjoy a geographic proximity to the UK. Airline and railway integration could allow BA to serve the local market without giving up long haul services, and could be used to feed traffic into the long haul route network. For an airline like BA, two apparent benefits seem to exist. First, it should be easier for a company like BA to win the competition against other network carriers in the domestic market rather than competing with them for markets outside the UK²⁵¹. Second, BA would be able to consolidate its services from Gatwick to Heathrow, for example on the London-Paris route, enjoying the network benefits of higher frequency (e.g. higher frequency of service to Paris will mean lower average connecting time for passengers). In addition, the benefits of BA's H&S network would also be enjoyed by UK passengers, and not only by overseas passengers, if many destinations in the UK gained access to BA's range of destinations from Heathrow.

A concern might be that the frequency of the HST service would not match the current frequency offer by airlines using aircraft, but there is no reason for such concern. Actually, evidence suggests that airline and railway integration might allow airlines to increase service frequency. IATA (2003) examined aircraft and railway service frequency on the following routes: Frankfurt-Stuttgart, Paris (CDG)-Lyon, Brussels-Amsterdam, and Madrid-Seville, and found that in all cases the railway services between the cities had much higher frequency. Evidence from the London-Paris route shows that currently AF and Eurostar offer the highest daily frequency on the route, 14 daily services from London to Paris (Eurostar, 2003b; Innovata, 2003). Another example is the Amsterdam-Paris HST line which is expected to have 32 services per direction (service every 30 minutes) by 2010 (IATA, 2003).

For many airlines, especially foreign airlines, operating at a congested airport, connection to the local railway network through a station at the airport is a good way, and perhaps the only way, to gain access to the domestic market. This market is often dominated by local

²⁵⁰ Even harder after the merger of AF and KLM (see section 5.1.2).

²⁵¹ Assuming home airlines enjoy some market power over foreign airlines (Doganis, 1991).

(national) carriers. Code-share agreements between the French railways (SNCF) and airlines such as Emirates, American Airlines, and United Airlines (IATA, 2003) are good examples.

In summary, airlines would benefit from airline and railway integration since it provides them with an additional capacity that is not attached to an airport runway and it offers them many advantages of a strategic nature. Specifically, it allows network airlines to take better advantage of the benefits from H&S operation, even at congested airports. These benefits seem to more than compensate for any OC losses following airline and railway integration. Thus, the short discussion above suggests that airlines have an incentive to adopt airline and railway integration provided the infrastructure is in place. LH, which already implement full airline and railway integration on some routes, is probably the best evidence.

5.1.2 Benefits to airports

The parallel between benefits to airlines and benefits to airports, from airline and railway integration, is easy to draw. Airports exist to serve airlines and it is the airlines' passengers who determine an airport's success. So any improvements to airline performance at a specific airport would make this airport more attractive to airlines and thus to more passengers. And vice versa, an airport that is attractive to passengers will draw more airlines to it. It is therefore in the interest of airports to become a hub in an airline's H&S system. Airports benefit from transfer passengers through increased traffic (landing charges) and when passengers consume any of the airport services during the transfer time.

Rail services to airports, when they consist of a fast and convenient transfer to the aircraft, could become part of the airport network of routes. This works for the benefit of airlines, as discussed above, and airports. IATA (2003) investigated the effect of the HST-Zuid line, which will allow HST services between Amsterdam, including Schiphol, and Brussels (and therefore also Paris and CDG), on the connectivity of CDG, Schiphol and Zaventem airports using IATA's connectivity model. The connectivity index measures the equivalent weekly frequencies for specific routes based on frequencies, travel time, and fares²⁵² and the following assumptions. First, KLM and AF have a code-share agreement with the HST TOC and therefore connection between aircraft and HST services is possible for services of these airlines only. Second, the HST stations at Amsterdam and Paris are located in Schiphol and CDG respectively, and for Brussels the HST station is Brussels Midi and an extra 30 minutes were assumed for connection between it and Zaventem airport. The connectivity index was calculated for three different scenarios: first, the 2002 air network with no HST network, second, the 2002 air network with the 2002 HST network, and third, the 2002 air network

²⁵² See IATA (2003) appendix D for a full explanation on how the connectivity index is constructed.

with the 2010 HST network (i.e. the Zuid HST line is completed). It was further assumed that passengers on HST services save 60 minutes by avoiding the ‘air’ check-in and check-out.

Table 52: Direct connectivity between CDG, Schiphol and Zaventem airports (equivalent weekly frequencies, one way¹)

Image removed due to third party copyright

Source: IATA (2003).

Considering first the direct connectivity between the airports, Table 52 provides evidence that HST can be a good substitute for runway capacity, perhaps even a better substitute (in terms of service frequency), when the airport is connected to the HST network. When the HST-Zuid is completed (scenario 3) on all three routes, the connectivity index increases substantially and especially on the routes to Schiphol, which enjoys the most from the completion of the HST line. For the Paris-Amsterdam and Brussels-Amsterdam routes, the actual service frequency²⁵³ was assumed to increase from 47 one-way weekly services in 2002 to 224 weekly services in 2010. This increase would not be feasible through an increase in aircraft services due to lack of runway capacity²⁵⁴.

IATA’s study also analyzed the indirect and hub connectivity of the airports under the same assumptions. Considering Schiphol and CDG only (Table 53), Schiphol benefits more than CDG from increased connectivity since between 2002 and 2010 the HST connection between Amsterdam and Brussels improved by far the most. The study concludes that the HST line “increases the competition between Amsterdam and Paris [airports] as hubs in both directions. Brussels [airport], on the other hand, does not benefit in this simulation in terms of hub connectivity like both Amsterdam and Paris [airports], due to its poor HST-airport connection, and the assumed non-existence of a code-sharing agreement [with the TOC]” (IATA, 2003: 55).

²⁵³ Not frequency according to the connectivity index.

²⁵⁴ It would also not be environmentally feasible at Schiphol considering the current ‘noise’ capacity of the airport.

Table 53: ‘Hubbing’ connectivity of Schiphol and CDG airports with respect to different markets (increase in equivalent weekly frequencies between 2002 HST network and 2010 HST network¹)

Image removed due to third party copyright

Source: IATA, 2003.

Considering the role of Heathrow as a hub airport which directly competes with CDG and Schiphol, it appears that Heathrow significantly loses from airline and railway integration at CDG and Schiphol and the completion of the HST-Zuid line. Particularly significant, from Heathrow’s perspective, is the increase in connectivity between CDG and Schiphol and destinations in North America, Heathrow’s primary market. Furthermore, capacity constraints mean that airlines operating from Heathrow focus more on the long-haul markets, and on these markets the HST allows CDG and Schiphol to improve their competitiveness by offering better connections to short haul services.

Since the study by IATA was published, AF and KLM have merged, effectively ending the competition between the airports for transfer passengers. This brings a whole new meaning to the benefits from airline and railway integration to the new AF-KLM airline. Not only that the new airline can consolidate the services on the route (saving runway capacity at both airports), it could withdraw aircraft services (further freeing valuable slots) and by doing so capture more of the Brussels market at the expense of Zaventem²⁵⁵. It is less clear, however, how the airports are influenced by the merger, but if AF-KLM uses the freed slots for other services, the airports’ passenger capacity would increase and the airports would benefit.

Heathrow provided aircraft services to 191 destinations in 2004 (BAA, 2004) and lack of capacity means that this cannot be increased and might decrease if, in order to increase services to high demand (international) routes, airlines stop services to low demand (regional) routes, a pattern that was observed by Graham and Guyer (2000). Currently, Birmingham, one of the biggest cities in the UK, has no direct access to Heathrow, and despite the size of Birmingham airport²⁵⁶ it cannot match the level of service and range of destinations offered from Heathrow. A railway station at Heathrow with a good airline-

²⁵⁵ This is a problematic situation for the airline under the model of integration adopted in the research since it assumes the airline to give up the city-centre to city-centre market. However, this can be overcome through the code-share agreement, between the airline and TOC, for airline and railway integration.

²⁵⁶ In 2003, the airport was ranked fifth in the UK in terms of ATMs (116,040) and passengers (9.07 million) (CAA, 2004).

railway interchange can solve this. The following illustrates the potential for Heathrow, and some airlines: “If you look up a journey between Birmingham and Hong Kong, you are usually offered just one connection in OAG, the airline timetable. This is either via Amsterdam or Paris...If however you travel via London, you are given the choice of 6 flights by 3 carriers (2 of them British) – but the timetable doesn’t give you the option of going via London because there are no flights from Birmingham to London” (Sharp, 2002: 2).

Airports do not benefit only from airline and railway integration per se. They also benefit from improved means of access and the benefits it provides. These benefits can be summarised as follows: “intermodality is seen by many major airports...as a way to increase their catchment area. Indeed railways can reach populations in areas where air services are not available or where frequencies are not good...Intermodality is also a way to offer more city linked services to a given airport versus another one, and strengthen competitive edge” (IATA, 2003: 99).

For Heathrow to increase its catchment area, it must have a railway station that is fully integrated with as many as possible of its terminals. With a railway station such as those at Frankfurt, Schiphol or CDG, Heathrow can become an important hub for regional, national and international rail services in the same way it became the country’s busiest bus and coach hub (BAA, 2002). Furthermore, Heathrow is likely to further increase its catchment area into other airports’ catchment areas and improve its position in comparison to its main (hub) rivals in Paris, Amsterdam and Frankfurt. At the same time, if Heathrow did not have such a railway station, it would lose to its main competitors for the same reasons. This becomes a real threat when Eurostar starts HST services directly to CDG²⁵⁷. For passengers originating in Kent, which is at the heart of Heathrow’s catchment area, CDG airport might be easier and quicker to access. In some circumstances, this might also apply to east Sussex, Surrey, and South Essex.

HST and conventional rail services to airports will improve the environmental performance of airports both through substitution of aircraft by HST and through a shift to public transport from the car as a means to access airports (for both passengers and employees). The latter could potentially reduce congestion on access roads to airports, and further reduce environmental impact²⁵⁸. For Heathrow in particular, this aspect of railway service is crucial. The decision to construct another runway at Stansted and not at Heathrow is due to the

²⁵⁷ Which it is currently considering (Brown, 2004).

²⁵⁸ The extent of the reduction is evident in comparing public transport and car egress journey emissions on the case study route (see sections 4.3.1 and 4.3.2).

environmental impact of a third runway and mainly its effect on NO_x levels around Heathrow. For the same reason, a second new runway might be built at Gatwick and not at Heathrow. This issue is further discussed later.

Finally, the airport also benefits from the perceived higher status image of rail access, certainly in Europe, and from the reduced need for parking which leaves more space for higher-earning commercial development (IARO et al, 1998)²⁵⁹.

In conclusion, airports, as stakeholders in airline and railway integration, are expected to benefit and perhaps even more than the airlines since they also benefit from improved accessibility. This could increase their catchment area and position in the competition with other airports. It can therefore be assumed that airports, in general, will be in support of airline and railway integration and would consider contributing towards the costs it entails.

5.1.3 Benefits to the railways

For any (private) transport operator and transport infrastructure owner, increased demand is generally a welcome problem. Likewise, for the railways, infrastructure owners and operators alike, airline and railway integration and railway stations at (major) airports lead to more demand for their services and are therefore a blessing.

However, “if you ask Deutsche Bahn what major problems and opportunities they face, collaboration with Lufthansa on reducing the number of short haul flights would be way down the list” (Sharp, 2002: 7). While this seems to hold equally for the railway industry in the UK with respect to services to Heathrow, it does not mean the benefits for the rail industry are insignificant or irrelevant. The problems currently faced by the railway industry in the UK²⁶⁰ might explain its reluctance to promote more cooperation between the two industries beyond the use of the railways as an access mode to airports on a city or regional basis²⁶¹. Nevertheless, this reluctance is considered here as a missed opportunity since airline and railway integration is expected to be beneficial to the railways as well. Furthermore, once construction of new runways begins, the scope for ‘integration’ reduces, mainly because scarce resources have been allocated to runway construction.

²⁵⁹ In contrast, “at a typical large hub airport in the US, 43% of revenue comes from non-airline sources, half of that from parking and rental cars” (Caves and Goosling, 1999: 138). In this case, airports probably have no incentive for passengers to use the train and not the car.

²⁶⁰ See House of Commons Transport Committee (2004) for discussion on the UK’s rail industry main problems. For review of railway structure and ownership changes around the world see Thompson (2003).

²⁶¹ See the Strategic Rail Authority’s (SRA) submission to the consultation on new runways in the South East (SRA, 2003b). See also section 5.2.

An increase in demand would also benefit the railways through improved LF. Since the marginal OCs of an extra passenger on board a rail service are virtually zero, the increase in LF means that increase in revenues, from increased demand, is virtually an increase in profit. “Intermodality is a way to maximise the number of passengers on trains, without any significant marginal costs other than the usual operating costs, if the rail network is in place” (IATA, 2003: 101). The effect of higher LF can be inferred by comparing the CBA results in seat units with the CBA results in passenger units (Tables 44 and 45 respectively).

Furthermore, the railways also, and as important, benefit by the ‘type’ of increased demand. This demand has, on average, special characteristics which allow the railways to charge premium prices on services to/from airports, especially when the rail is used as an access mode. In this respect, it is important to distinguish between the airline and railway integration market and the access to airport market.

On the airline and railway integration market, the HST service would probably stay in competition with aircraft services of airlines not adopting airline and railway integration, and mainly low cost airlines. The financial analysis (section 4.1) showed it would be hard for the ‘integrated’ airline-railway service to compete with the remaining aircraft services and, even more so, with low cost airlines services. However, under some circumstances, the airline HST service might be able to compete even with the low cost services. The basis for airline and railway integration is that the focus of the HST service is on the city-centre to city-centre market. Therefore, and considering the relatively low LF of HST services, the marginal OCs for serving the airline passengers could be virtually zero²⁶². In this case, the TOC could reach an agreement with the airline in which the cost for the airline of using the HST for its passengers is less than the aircraft OCs²⁶³ and the TOC still makes a profit. Furthermore, when the HST service offers travel time savings, premium prices, in comparison with the flight service, can be justified, especially for business passengers. If the better journey conditions of the HST service (as discussed in section 4.2.2) are perceived by the passengers, there is even more scope for premium prices to be set. Hence, there is scope for the TOC, and railways in general, to gain financially from airline and railway integration, further strengthening the financial viability of such services which already, usually, do not receive

²⁶² When the HST route is not extended to serve the airport, for example in the case of the Frankfurt-Stuttgart route. On the case study route, the HST service is extended 30 km (from London to Heathrow) to serve the airline passengers. The HST OCs per seat for 30 km is €1.71, which can be seen as the marginal OCs the TOC incur from extending the service to Heathrow.

²⁶³ Calculated at €26.41 per (A320) seat for the case study route (see section 4.1).

any subsidy. The situation illustrated above would of course benefit the airline as well and would allow it to successfully compete with the low cost airlines, or at least save on OCs²⁶⁴.

The access-to-airport market is another profitable rail market. The characteristics of the access to airport journey, mainly the fact that its cost for the passenger is often a small part of the overall journey cost and the possible consequences of missing the flight, means that the TOCs can charge premium prices on such services²⁶⁵. The Gatwick Express and the Heathrow Express rail services to Gatwick and Heathrow respectively are both profitable services, at least on the operational level, which have never received any subsidy (Sharp, 2002).

Often, the overall level of traffic is increased following the introduction of an additional link, or even additional capacity on an existing link, due to traffic generation (or induced demand)²⁶⁶. This phenomenon is apparent following the introduction of HST services. "The data show that the interconnection of the rail network with CDG airport generates additional journeys equal to an increase of almost 30% over the number of passengers using the two modes" (Pavaux, 1994: 6). López-Pita and Robusté (2004b) estimate that induced demand would represent 10% of the demand for the HST services after the opening of the Madrid-Barcelona HST line. It is not certain that airline and railway integration would result in induced demand since it is not expected to increase capacity on the route but only to substitute the aircraft services with HST services. If it does lead to induced demand, this would benefit the railway, the airlines and the airports. Such benefits are more significant to the railways since overall, and in the long term, the ATI is not expected to meet even current forecasts for growth in demand for air services. However, a railway station at Heathrow that would offer a through HST and conventional rail services²⁶⁷ would probably lead to induced demand, in addition to the demand shifted from the aircraft and other access modes.

Other benefits to the railways are harder to quantify but, nevertheless, seem to exist. IATA (2003) argues that airline and railway integration could bring more foreign passengers, unaware of HST in Europe, to use them in the future. Those passengers, and domestic tourists as well, could be attracted to use the rail network to explore other destinations on the rail network and use the railway to reach destinations outside the major cities. Another

²⁶⁴ This was not emphasized in section 4 since it implies comparison between (aircraft) average OCs and (HST) marginal OCs on the route, which is methodologically inconsistent.

²⁶⁵ The relatively high VTTS on access journeys to airports is evidence for the possibility to charge premium fares.

²⁶⁶ See Appendix B.

²⁶⁷ Henceforth, a 'through station' will mean a rail station which is on a line (hence services run 'through' it) as opposed to at the end of a line/branch. The rail station at Gatwick is a 'through station' while the station at Stansted is currently not.

probable benefit to the rail industry relates to the relative success of the ATI in the post deregulation years²⁶⁸ which the railways can learn from. Staniland (2003) identified a process where airlines exchanged a 'culture of production' for a 'culture of service' following deregulation, and such a change in culture is necessary in the railway industry for it to win back market share. By cooperating and increasing the interaction with the ATI, the shift to a culture of service can be facilitated.

"There are two types of rail service which can be profitable – the airport express...and the long-distance InterCity service" (Sharp, 2002, 2). This summarises the main benefits to the railways from providing services to airports. There are other benefits, as outlined above, and overall this suggests that the railways are likely to benefit from airline and railway integration. The extent of these benefits depends on the amount the railways would have to contribute towards the investments required for airline and railway integration.

5.1.4 Conclusions

The airlines, the airports and the railways have much to gain from airline and railway integration directly and indirectly, for example through the provision of conventional railway services to Heathrow which are expected if a HST station was built at the airport. Although these benefits were not quantified, the discussion indicated they are probably significant.

The main conclusion with regard to airline and railway integration is that the benefits to airlines from the freed slots (whether sold or used for other services) and from improving the network coverage and level of service seem to outweigh any OC losses that might occur, and in addition, the potential benefits to airports and the railways could also counterbalance any likely losses to the airlines. Next, the discussion turns to the policy context of airline and railway integration.

²⁶⁸ In terms of growth in operation, reduction in operating costs, and reduction in the costs of its services to customers, but not necessarily in terms of financial success. Button (2004) claims that the post deregulation airline industry is inherently economically unstable (due to its "empty core" characteristic), but it still seems to perform better than the railway industry, especially from the customer perspective.

5.2 Airline and railway integration in a transport policy context – HST line vs. runway capacities at Heathrow

The first prerequisite for airline and railway integration is the availability of HST services at the airport. In the absence of the infrastructure for airline and railway integration the discourse on airline and railway integration shifts from the airline to the airport. However, despite the privatisation and commercialization processes undergone by most major airports, specifically in the UK (see Humphreys, 1999), the nature of the decisions means that they are not taken at the airport level. Such decisions would be taken at the regional and national levels where public policy considerations overcome commercial objectives, the latter naturally playing a role in the former. It is not different for a HST connection to an airport than it is for an additional runway or terminal for an airport.

The main concern of this research is with the wider implications of airline and railway integration, and less its importance to the airlines or the airports²⁶⁹. Therefore, examining integration in a policy context, assuming it reflects society's interest, is crucial. This section continues to explore the benefits from airline and railway integration but from society's perspective. The case study route means that the discussion will focus on the UK's transport policy. Although the discussion focuses on the UK and Heathrow, the lessons it provides apply elsewhere. To emphasize the official views of policy makers, quotes from policy documents are used extensively.

The discussion begins by portraying the main arguments to supply additional runway capacity in general and at Heathrow specifically. Based on the same arguments, the case for supplying HST services at Heathrow, as an alternative to runways, is argued. Finally, the UK's HST policies, and rail policies in general, are considered before conclusions are drawn. The conclusions also draw attention to one aspect that policy makers are likely to be concerned with before recommending integration, and that is its effect on competition.

²⁶⁹ The focus on the airlines, however, is because in a liberalised ATI it is mainly an airline's decision whether to adopt airline and railway integration, as repeatedly emphasized in this research.

5.2.1 The case for provision of extra runway capacity in the South East of England and at Heathrow

We recognise the immense value to the UK of Heathrow's status as an international hub airport and we want to see that continue

(DfT, 2003b: 11.7, my emphasis)

The above quote, from the recently published aviation White Paper, provides a clear indication of the context in which the Government considered provision of extra runway capacity in the South East in general and specifically at Heathrow. The value of the ATI to the UK's economy²⁷⁰, in addition to its contribution to accessibility, were also prominent in the consultation on "the future development of air transport in the UK" (DfT, 2003a) and in the consultation on "the future of aviation" (DETR, 2000a) which preceded the White Paper²⁷¹.

The same economic argument dominated the public inquiry which recommended the construction of a fifth terminal (T5) at Heathrow (Vandermeer, 2001). The inspector concluded that "unless Heathrow is able to maintain its competitive position there must be a substantial risk that London's success as a world city and financial centre would be threatened. By ensuring the continued success of Heathrow, Terminal 5 would make a major contribution to the national economy" (Vandermeer, 2001: 34.5.8), and he also concluded that "it would be most unwise to place in jeopardy the future of any enterprise which made such a substantial contribution to the national economy...Heathrow's importance is recognised by the government and by the local authorities but its role depends upon its ability to compete successfully with other European airports" (ibid: 9.4.1).

In the debate on new runways in the South East, the government also emphasized other benefits Heathrow brings and tied them to economic benefits. It claimed:

Airports with substantial capacity can support services to a wider range of destinations and a greater frequency of services than could be supported by local demand alone...Heathrow's extensive route network is only viable because of the large number of international passengers transferring through the airport. As a result, UK travellers and businesses benefit from having direct flights to more destinations and higher frequencies. This is a leading factor in attracting inward

²⁷⁰ Through generation of economic growth, employment, and foreign investments (see section 2.1.3).

²⁷¹ It seems strange, however, that the consultation on new runways took place just before the policy was established.

investments to the whole of the UK. Regional travellers benefit from having an increased range of destinations served one-stop via a hub

(DfT, 2003a: 2.20).

The T5 inquiry referred more specifically to Heathrow's position as a transfer airport and stated that: "Transfer traffic carried by British carriers represented an invisible export while domestic traffic transferring abroad to a foreign airline represented a loss of revenue to a UK carrier" (Vandermeer, 2001: 9.3.3). BAA estimated that "if Terminal 5 were not provided the loss of transfer traffic would mean that UK carriers would lose some £1bn in revenue in 2016" (ibid). Furthermore, the inspector accepted BAA's view and concluded that transfer passengers "made a valuable contribution to the revenue of UK airlines and secured the maintenance and improvement of the range and frequency of services to the benefit of all air travellers" (ibid: 7.2.7).

For the same (economic) arguments, a third runway at Heathrow is proposed. The benefits from providing this runway are estimated at £12 (€18) billion, or £7.8 (€11.7) billion net benefits²⁷² (DfT, 2003a).

The House of Commons Transport Committee (2003) highlighted the social importance of increasing capacity at Heathrow. "The provision of high quality air access to [the] main London airports is essential. The regions must have guaranteed access to international routes that will support continued inward investment" (ibid: 53). However, due to capacity constraints at Heathrow, the UK regions are losing access to this airport, mainly because these routes are not as profitable as others. Between 1988 and 2003, the total number of domestic services to Heathrow fell from 855 to 562 (ibid). The White Paper also recognises that for many areas of the UK the availability of air transport services to London is crucial (DfT, 2003b).

Keeping Heathrow's position as a transfer hub for international passengers, thus preserving high frequency on international routes, maintaining access to Heathrow from the regions, and sustaining access to international routes from the regions, does not go hand in hand in a capacity-constraint airport. Suggestions for addressing either of the problems do not offer a real reconciliation between the two rolls envisaged for Heathrow, and no reconciliation with the environmental limitations. The House of Commons Transport Committee (2003) suggests the following: slots will be protected for use of domestic regional services at Heathrow; one of the smaller airports near Heathrow will be designated as a feeder airport

²⁷² Based on a 6% discount rate. BA estimated that the third runway at Heathrow would generate £37 (€55.5) billion worth of economic benefits for the UK over a 50 year period (BA, 2003a).

(possibly Northolt or Redhill), which will require railway connections with Heathrow; and the committee also “strongly support improvements to the links between Gatwick and Heathrow, so that passengers from regions with access to Gatwick can transfer onto Heathrow quickly and easily” (ibid: 57). Finally, the committee suggests increasing the capacity of Luton airport²⁷³ (ibid). These suggestions offer better access to Heathrow from the regions but would not improve Heathrow’s position as a hub airport.

If new capacity is provided outside Heathrow, even with better railway connections between the London airports, it cannot replace direct flights from the regions to Heathrow²⁷⁴. One of the disadvantages of London, in comparison with its competitors, is that while London has six runways compared, for example, with the five in Amsterdam, in London they are spread over five airports compared with one in Amsterdam. Therefore, although London has more runway capacity it is not as attractive for transfer passengers as Amsterdam. If slots at Heathrow were reserved for regional services, then Heathrow’s position of a hub airport would further deteriorate.

The government proposes that “a new 2000m long runway would be built to the north of the existing airport...This is about half the length of the existing runways, and could be used only by smaller narrow-body planes” (DfT, 2003a: 7.7), i.e. for short haul services only. The characteristics of the proposed third runway at Heathrow means that it would probably not offer the capacity required for Heathrow to keep its hub position, which is already weak²⁷⁵, especially if new capacity is reserved for regional services. Nevertheless, any increase in Heathrow’s capacity would improve its position as a hub airport and would improve access from the regions. The Government view is that “additional capacity at Heathrow would generate the largest direct net economic benefits of any new runway option” (DfT, 2003b: 11.50)²⁷⁶.

In the White Paper (DfT, 2003b), the government recommended the construction of a new runway at Stansted first. The reason was the environmental impact associated with the new Heathrow runway and concerns about “compliance with the mandatory air quality limit

²⁷³ In its general recommendations, the committee suggests ending BAA’s monopoly over London’s largest airports and this is probably the reason why Luton and not Gatwick or Stansted is proposed.

²⁷⁴ This will result in a three-segment-journey (for example, to Gatwick, between Gatwick and Heathrow, and from Heathrow) with two transfers. The implications of this for passengers were demonstrated in 4.2. Such a strategy would not work in practice and would lead passengers to use, as already is the case, continental hubs instead of Heathrow.

²⁷⁵ See section 2.1.1.

²⁷⁶ The quote continues: “and although not easy to quantify with certainty, there is little dispute that the range and frequency of Heathrow’s services bring wider benefits to the national economy. It appears to be generally accepted that without additional capacity, Heathrow’s route network will tend to shrink over time, most likely to the advantage of other continental hub airports” (DfT, 2003b: 11.50).

values for NO₂” (ibid: 11.54). A third runway at Heathrow was chosen as the second runway to be provided, after the runway at Stansted, but subject to meeting environmental restrictions. If these were not met, a second runway at Gatwick was recommended.

The White Paper makes it clear that the development of a third runway at Heathrow will require a sixth terminal, probably between the current North runway and the proposed third runway (Figure 14) (DfT, 2003b). Such a terminal would further fragment Heathrow’s design and would not be attractive for passengers requiring transfer to flights departing from other terminals (see below).

In conclusion, it is likely that Heathrow would continue to struggle to keep its international position as a hub airport and at the same time would continue to provide limited access to services from regional airports in the UK, even with a third runway. Even if a third runway could improve the situation, this would come at a very high environmental cost, which currently does not allow its development. As a result, the economic and social benefits Heathrow could provide to the UK, according to the Government, would probably not be realized.

Figure 14: The layout of the proposed 3rd runway and 6th terminal at Heathrow in relation to the existing facilities

Image removed due to third party copyright

Source: DfT (2003b).

5.2.2 Airline and railway integration as an option to increase capacity at Heathrow

Airline and railway integration in the way defined here means that a link between an airport and a HST network is similar in many respects to providing additional runway capacity. Therefore, increasing Heathrow's capacity through a HST link would bring the same benefits that were described above, if it provides the same capacity, but at a much lower environmental cost and with other benefits.

The importance attributed to Heathrow's competitive position against its main European rivals, mainly as a transfer airport, dominates a significant part of the debate on the future of air transport in the UK. It also dominated the T5 inquiry (Vandermeer, 2001). In 2002, CDG's capacity in terms of ATMs was already higher than Heathrow's, while Frankfurt and Schiphol airports were not far behind²⁷⁷. However, while Heathrow's competitors are constantly perusing runway expansions, they have all already invested in railway and HST stations which allow them to benefit from improved (public transport) access, some from airline and railway integration, and possibly increased catchment area (see section 2.3). One of the cited reasons for constructing the HST station at CDG was to give CDG "the greatest chance of competing with other European airports" (López-Pita and Robusté, 2004a: 5).

In addition to extra capacity, HST infrastructure could provide Heathrow with two important benefits. First, it would allow Heathrow to maintain its leading position in terms of passenger throughput²⁷⁸, by freeing up runway capacity used for short haul flights which are, predominantly, operated by small aircraft. Since airport revenues from passengers are larger than revenues from aircraft, passenger capacity is more important than ATM capacity. Furthermore, the short haul routes tend to have the highest frequency in an airline network, which means these routes take a relatively large share of the runway capacity but carry a relatively small share of the airport passenger capacity. Already today, Heathrow uses its scarce runway capacity more efficiently than its rivals in terms of passengers carried per ATM²⁷⁹.

²⁷⁷ The ATM capacities of these airports in 2002 were as follows: CDG: 510,098 (ranked 6th in the world); Heathrow: 466,554 (13th); Frankfurt: 458,359 (15th); and Schiphol: 417,120 (21st) (ACI, 2004).

²⁷⁸ Passenger capacity in 2002 was at Heathrow: 63.47 million passengers (ranked 3rd in the world); at Frankfurt: 48.35 (7th); and CDG: 48.12 (8th); and at Schiphol: 39.96 (9th) (ACI, 2004).

²⁷⁹ This can be computed from the two previous footnotes as follows: Heathrow: 136 passengers per ATM, Frankfurt: 105, Schiphol: 96, and CDG: 94. For comparison, in 1999 the figure for Tokyo's Haneda airport, serving Japan's domestic market, was 224 passengers per ATM (ACI, 2000). This can be associated with the dominance of the Shinkansen on the (aircraft) short haul routes from Tokyo!

The second advantage to Heathrow from HST infrastructure is the potential to integrate its fragmented terminal capacity. After the completion of T5, Heathrow's terminal capacity will be spread over five terminals at three different locations around the runways (and possibly six terminals at four different geographical locations if the third runway is approved (see Figure 14)), a major disadvantage when competing for transfer passengers. Even terminals 1, 2 and 3 at Heathrow²⁸⁰, which are situated in the same geographical area of the airport, lack adequate connections between them. This is in contrast to Schiphol, where all three terminals are physically connected by one big hall situated **directly above** the railway station. A HST station located under Heathrow's CTA would consolidate Heathrow's terminals and would better serve Heathrow's needs compared to a sixth terminal physically separated from the other five²⁸¹.

In addition to the two advantages, a HST station at Heathrow which would allow connection between the airport and the rail network (including a future HST network) would further increase the number of domestic destinations served by the airport, a concern raised by the House of Commons Transport Committee (2003). It would allow many more UK passengers to use Heathrow as a hub rather than its European competitors²⁸², and cities like Birmingham would gain access to the 'national' airport and to the range of world connections it offers.

Before the current debate on air transport policy began, the government published its White Paper on transport policy (DETR, 1998). In it, two themes and objectives were emphasized: integrated transport, and sustainable transport. By definition, a railway link to Heathrow, whether or not HST, fulfils the first objective. In reviewing the White Paper, with regard to air transport policy, Graham and Guyer (2000) noted that there is no national policy for rail-air integration and that only three airports (Gatwick, Birmingham, and Southampton) have direct access to inter-city railway services.

With regard to sustainable transport, which is usually used to indicate that environmental impacts should be reduced and accounted for, this research clearly shows that increasing an

²⁸⁰ Often referred to as the Central Terminal Area (CTA).

²⁸¹ A sixth terminal between the new and the old runways (Figure 14) serving the short haul flights using the new runway would prevent fast transfer to the long haul flights operated from other terminals, and thus would not contribute to Heathrow's position as a transfer airport. If, however, the main airlines using Heathrow operated all their flights from one terminal (for example, BA from T5), then if all short haul flights used the new (short) runway, taxi time, and hence flight time, would probably increase considering the location of T5 and the new runway.

²⁸² The CAA noted that 16 regional airports in the UK have access to Amsterdam, 11 to Paris, 8 to Brussels, and 4 to Frankfurt and Copenhagen (House of Commons Transport Committee, 2003). It can be assumed that a significant part of the traffic to these airports is in order to transfer to other flights from these airports. Heathrow's list of destinations in 2004 included only 7 regional airports in the UK (including: Aberdeen, Belfast city, Edinburgh, Glasgow, Leeds/Bradford, Manchester, and Newcastle) (BAA, 2004).

airport's capacity through HST and not aircraft services is more sustainable²⁸³, and also using rail and not car as an access mode is more sustainable. The Environmental Audit Committee (2003) claims that including the cost of aviation emissions would entirely wipe out the economic case for an expansion of runways. Furthermore, "the most difficult issue confronting expansion of Heathrow concerns compliance with the mandatory air quality limit values for NO₂ that will apply from 2010" (DfT, 2003b: 11.54). The analysis clearly indicated a reduction in NO_x emission as a result of airline and railway integration (section 4.3.2). If most of the HST link to Heathrow (from London) would be in tunnels there would also be scope for noise reduction.

In addition to the above, the formal decision letter on the construction of T5 stated that: "The secretary of state accepts the recommendation that a condition should be imposed to limit aircraft movements to no more than 480,000 atms. He is aware that in 2000 Heathrow handled nearly 460,500 atms with a passenger throughput of just below 65 mppa" (DTLR, 2001: 30)²⁸⁴. Only eight months after this statement was made, the first official suggestion to construct a third runway at Heathrow (which would increase capacity to 655,000 ATMs) was published²⁸⁵! A HST link to Heathrow would increase capacity without requiring an increase in the annual ATMs²⁸⁶.

In summary, a HST link to Heathrow could offer the same benefits as a third runway and even more, and at a much lower environmental cost. Such a link would allow Heathrow to strengthen its competitive position as a hub airport through freeing up capacity for long haul routes and opening up access to Heathrow from the regions, and thus would secure, and improve, Heathrow's social and economic contribution to the UK. In this case, keeping Heathrow's position as a transfer hub for international passengers and maintaining access to Heathrow from the regions does go hand in hand. Finally, connecting Heathrow with the railway network means taking real steps towards an 'integrated transport' system.

The extent to which HST services at Heathrow could provide the benefits predicted for the third runway depends on the type of station built and the development of a future HST network in the UK. It is apparent that in order to provide a real alternative to the third

²⁸³ The analysis in this research is especially important and relevant since the proposed new runway is planned to cater for short haul flights only.

²⁸⁴ MPPA – Million Passengers Per Annum.

²⁸⁵ Interestingly, in the Terminal 4 public inquiry, the government announced that this would be the last major expansion of the airport, and specifically that there would not be a Terminal 5 (Vandermeer, 2001).

²⁸⁶ To put airline and railway integration at Heathrow in context, the following can be considered. Recommendation to build the £2.5 (€3.75) billion terminal was granted with a 4.2% restriction on increase in ATM, while the route to CDG alone consumes about 4.2% of the airport ATMs (section 4.4.3).

runway Heathrow should have a rail station that provides through services for both HST and conventional rail, and, optimally, it should be located within walking distance of the major terminals (ideally underneath the CTA). The benefits and implications of such a station make the rail industry a major stakeholder in the matter. Therefore, in a policy context, the UK's rail policy needs to be examined, especially with respect to HST.

5.2.3 HST policy in the UK

In September 2003, the first HST line was opened in the UK. The 74 km section is section 1 of the CTRL and in 2007, section 2 (39 km) is expected to be completed, connecting London with Europe by HST. For the near and medium future, this is the UK's HST network. Despite the development of the HST network in the last two decades, especially in Europe, plans to develop such a network in the UK are still not on the agenda. In its Strategic Plan for 2003, the Strategic Rail Authority (SRA)²⁸⁷ scheduled a consultation on a South-North high speed line study but this has not yet been published.

According to the CfIT (2004) there are good reasons for the lack of a HST network in the UK. It argues that during the 1980s and early 1990s, the UK lacked the favourable conditions for the development of a HST system, unlike its continental neighbours. In addition, policy to reduce public subsidy for the railway meant that projects had to be justified on a purely commercial basis, which was not the case for HST elsewhere in Europe. The financial crisis in the rail industry, which led to the collapse of Railtrack²⁸⁸ in 2001, and its replacement by Network Rail, a not-for-profit company, is probably further responsible for HST being omitted from the SRA plans for the near future.

Nevertheless, there is a growing number of reasons for putting plans for HST in the UK (higher) on the transport policy agenda, certainly when looking beyond the shorter term problems faced by the industry. The CfIT study on international comparisons of HSTs (CfIT, 2004), the CfIT study on the environmental impact of aircraft and HST (CfIT, 2001a), and the upcoming SRA consultation might signal that a change in attitude towards a HST network in the UK is already taking place.

²⁸⁷ The Strategic Rail Authority (SRA) is the public sector body responsible for setting and specifying the framework and strategy within which the UK railway industry operates. In January 2002, it published its first 'Strategic Plan' where the strategic priorities for Britain's railway over the next ten years were set out. The SRA is responsible for delivering the plan, within the resources available, and for achieving the Government's key targets for the industry, including 50% growth in passenger kilometers and 80% growth in freight moved (SRA, 2003a).

²⁸⁸ The private sector company established after rail privatization to own and manage the rail infrastructure.

More important, the conditions have changed. “The case for high speed rail construction in Britain is now stronger than it would have been in the 1980s...At that time, there was spare capacity on the British national rail network, but this now faces severe constraints” (CfIT, 2004: 64). In addition, “the upgrade of the West Coast Main Line has demonstrated that resolving these [capacity] constraints on the existing lines of route, whilst seeking to protect a complex pattern of ongoing services, would be disruptive and expensive” (ibid)²⁸⁹. Furthermore, following examination of different HST systems around the world, the CfIT notes that “it was clear from the case studies that decisions to construct high speed lines had not, historically, been based on economic appraisal alone, or at all, but were made for other reasons” (ibid). Evidence from Japan, France, Germany, Italy and Spain suggest this was not necessarily a wrong decision. These ‘other reasons’ which led to the construction of HST lines in other countries are not necessarily inappropriate or less robust; they might just be hard to quantify in monetary units.

The lack of reference to HST in the rail industry agenda might be justified, especially since the industry is faced with other problems in the near future. However, this cannot justify the lack of reference to the potential of the HST to substitute aircraft in the SRA’s contribution to the consultation which led to the aviation White Paper (SRA, 2003b), especially since the White Paper adopts a 30 year horizon and considering the nature of the SRA role.

From the outset the SRA limits its role in the debate to access issues. It states that “the work that the authority has carried out is not intended to suggest which airports are most suitable for growth...But the authority would like to set out the main rail surface access issues that need to be considered” (SRA, 2003b: 4). Yet, the potential for HST to substitute aircraft through airline and railway integration depends on deciding at which airport growth should take place.

Perhaps even more striking, considering the experience gained by Heathrow’s main rivals, is that in referring to the future South-North HST line, the SRA proposes a branch line that will connect the airport with the HST line (ibid). A branch line means that the demand for rail services is not high enough to make the airport station an important stop on routes passing through or near the airport. It also means fewer destinations and a smaller geographical area covered by the (airport) station (see section 2.3.1). Furthermore, the nature of a branch line means that for passengers to enjoy the services on the new HST line, they would have to use a service to a station on the HST line and transfer there. This completely undermines the possibility of the railways to benefit from a high level of demand from the airport on one

²⁸⁹ The CfIT estimates that “the cost of a major high speed line from London to northern England would be comparable to the cost of the West Coast Main Line upgrade” (CfIT, 2004: 69).

hand, and of Heathrow to benefit from airline and railway integration and improved rail access on the other hand. The railway stations at CDG, Frankfurt and Schiphol are all important stops on the routes passing through the airports. The demand generated by Heathrow for different types of rail services is certainly enough to make it a major stop on a future HST line. Furthermore, Heathrow's geographical location with respect to the geographical alignment of the South-North and East-West transport corridors from London is favourable, for example with respect to the WCML and the Great Western Lines, certainly more than the other major airports in London.

In addition to the SRA (and BAA), the government seems to be 'blind' to the idea, or potential, of airline and railway integration. It states that: "the upgrade of the WCML is projected to reduce significantly point-to-point air passenger demand between Manchester and London, although less so for those air travellers using London airports to join connecting flights (DfT, 2003a: 151, my emphasis). Given LH, AF, and KLM's use of airline and railway integration at Frankfurt, CDG, and Schiphol respectively, the failure to recognise that the WCML upgrade can serve 'those air travellers using London airports to join connecting flights' under airline and railway integration is disappointing. Similarly, the White Paper considers long-distance rail service as a substitute to the aircraft only under competition, and not integration, and sees little scope for mode substitution in general. Furthermore, the White Paper emphasizes that for passengers wishing to transfer in London to connecting flights, rail cannot offer a real alternative to flights (DfT, 2003b).

The failure to recognise the importance and potential benefits from high quality rail services at Heathrow is not only with regard to the future HST. More concrete proposals from the SRA include a rail line west of Heathrow with a station situated to the west of T5 and a connection from this station to T5 (SRA, 2003b). Such a proposal would not allow fast and smooth interchange between the modes and would undermine BAA's target of increasing public transport share in the journeys to/from Heathrow. Again, it underlines the failure to appreciate the importance of good rail connections to (major) airports.

The target to increase access to Heathrow by public transport, and specifically by rail, results in different proposals which are gaining momentum. For example, the Airtrack proposal to connect T5 with the rail network South of Heathrow (AirTrack Forum, undated) and plans to introduce a new Heathrow Express service (called 'Heathrow connect') which will serve London western suburbs from July 2005 (Railway Gazette International, 2004). Yet, the most important project in this context is the 'Crossrail' project. The Crossrail project includes development of an East-West rail line which will include a station at Heathrow and will allow fast running East-West trains to stop at the airport (Crossrail, 2003). It will

provide a significant increase in rail access capacity and rail access from much wider geographical area to Heathrow. The line is planned to include stations at Stratford, and Ebbsfleet where passengers could transfer to the HST services on the CTRL. The above projects undermine the benefits from airline and railway since they answer the need for better rail access to Heathrow, but they would not allow integration to take place and with it the associated benefits. In addition, resources allocated to finance these projects, and mainly the Crossrail project, estimated at €15 billion (ibid) would not be available to support the provision of infrastructure for airline and railway integration. The private sector (BAA) is expected to significantly contribute to these projects.

In the context of HST in the UK, it is useful to note the EU's rail policy. The EU puts the expansion of the HST network high on its transport policy agenda, mainly through the TEN projects. One of the EU priority projects is the WCML²⁹⁰ and the EU general approach means that it envisages a connection between this line and the rest of Europe through the CTRL. The EU assists in financing the priority projects, strongly supports substitution between aircraft and HST services²⁹¹, and aims to revitalise the community's railways (CEC, 1996). Hence, the EU is likely to assist in financing a link between the CTRL and the WCML via Heathrow. Another important aspect of the EU rail policy is the regulatory reform that is taking place with the aim of reaching 'open access' on all domestic and international passenger and freight markets (Nash and Rivera-Trujillo, 2004)²⁹². This opens the way for new initiatives between TOCs and airlines to implement airline and railway integration.

In conclusion, the review of rail policy in the UK and proposals for future rail services at Heathrow reveals a failure to recognise the importance and the benefits rail services at Heathrow (high speed and conventional) could bring to the ATI, the rail industry itself, and consequently to the UK. It seems that both industries aim to minimize the interaction between them. It is as if aviation and railways are two separate things when it comes to transporting people from A to B.

The signs of change in the attitude towards a HST line in the UK might be (too little) too late for airline and railway integration, considering that the policy for the next 30 years has been laid down, with no proposals to allow for future airline and railway integration at Heathrow.

²⁹⁰ However, as noted above, it was decided to upgrade this line rather than to rebuild it as a HST line.

²⁹¹ See section 2.1.5.

²⁹² Experience gained from regulatory reforms in the rail industry are summarised by Thompson (2003). It is surprising that in the literature on regulatory reforms in the railways no reference is made (at least none was found) to the experience gained in the airline industry. There are certainly enough similarities between the industries (although probably more differences) for the rail industry to gain from the ATI's experience.

Although this research does not aim to promote HST in the UK, the case for airline and railway integration and the other benefits from a 'through station' at Heathrow are certainly important aspects in the debate on a future HST network in the UK.

5.2.4 Conclusions

This section argues that the strong (economic) arguments, given by the government, in support of the construction of new runways in the South East and at Heathrow equally apply to the construction of a HST link to Heathrow to replace the proposed third runway. In addition, it was argued that providing a high quality of (HST and conventional) railway services at Heathrow would provide many benefits other than those from airline and railway integration. Providing the infrastructure for HST and a conventional 'through station' at Heathrow would be more consistent with the declared responsibility of the Government "to balance the economic, environmental and social costs and benefits" (DfT, 2003b: 1.9) of the ATI when setting the air transport policy. It will also be much more consistent with the general transport policy which aims at integration between the modes. Finally, it will be consistent with EU policy, which encourages mode substitution and revitalisation of the railways.

An IATA study states that "an airport needs multiple access routes to create critical mass for the rail network" (IATA, 2003: 99), and Heathrow certainly has the mass (demand) but not the multiple access routes. In this respect, the study notes that "[multiple access routes is] the case at FRA [Frankfurt airport] where the airport is linked to all rail tracks serving cities to the south of Frankfurt. At AMS [Schiphol], the airport is linked to the HST line and also to many domestic cities. At CDG, many HST lines stop. Heathrow clearly loses out in this respect" (ibid, my emphasis). What is clear for IATA is missed by policy makers (and both the air and rail industries) in the UK.

From a transport policy perspective, there seems to be a clear case for airline and railway integration. One thing that might concern policy makers, however, is the effect of airline and railway integration on the level of competition on the route and its implications. This is discussed below.

5.2.4.1 The effect of airline and railway integration on the level of competition

A possible outcome of airline and railway integration is reduced competition on the route following the commercial agreement between the (hub) airline and the TOC which would be the basis for airline and railway integration. This is considered the main, and so far the only,

significant disbenefit of airline and railway integration. Examining this matter requires a detailed analysis and more information on the exact agreement between the airline and the TOC and the market conditions under which integration takes place. However, some observations can be made to indicate whether this is likely to be a major impedance for airline and railway integration.

Table 54 shows that the HST dominates the market on both the London-Paris and London-Brussels routes. After the HST, the biggest market share is held by scheduled airlines followed by low cost airlines. In September 2003, travel time on the HST services was reduced following the opening of section 1 of the CTRL, leading to increased market share of the TOC. This change indicated that the HST services gain market share mainly from the scheduled airlines, the ones likely to adopt airline and railway integration and which operate from Heathrow, and less from the low cost airlines. This suggests a significant reduction in the level of competition following airline and railway integration.

Table 54: Market share on the London-Paris and London-Brussels routes (percentage)

Image removed due to third party copyright

Source: Eurostar (2004a).

There are also arguments which suggest competition would still exist. First, airline and railway integration would increase the competition between airports, and thus the respective hub airlines. So, if both AF and BA adopted airline and railway integration, they would do so from different airports and thus would continue to compete²⁹³. Second, it also seems that competition with the low cost airlines will continue and even strengthen. And third, the scheduled (hub) airlines compete at a network, and not a route, level. Thus, even if BA, AF and bmi adopted airline and railway integration, they would still compete in the sectors where they still operate aircraft. The fact that BA, AF and bmi are all members of a different

²⁹³ Against this argument, it can be argued that since only one TOC operates on the routes, both AF and BA would have to reach an agreement with the same TOC and there would be a risk for a cartel.

alliance further emphasizes that the real competition between these airlines is not so much at a specific route level.

If the completion of the CTRL would have a similar effect on market share as the opening of the CTRL section 1, then even before airline and railway integration takes place the TOC would have about three quarters of the market, enough to alert competition regulators. Thus, the competition issue is less related to airline and railway integration and more to mode substitution in general and the fact that only one TOC operates on the route. However, airline and railway integration would probably further reduce competition. In this case, integration should be considered on the same basis that every code share agreement (or merger) between two airlines is considered. The unstable financial situation of the ATI (due to its 'empty core' characteristic (Button, 2004)) leads authorities to allow more and more of these agreements and consolidation in the airline industry through airline alliances or mergers (e.g. AF-KLM).

5.3 Airline and railway integration in practice

One of the main aims of the research is to provide an empirical contribution to the debate on mode substitution. This requires discussion on airline and railway integration in practice, how much does it cost, how would it 'blend' into the ATI operation, etc. First, the investment required to provide the infrastructure for airline and railway integration at Heathrow was estimated and compared to the cost of a new runway at Heathrow (section 5.3.1). Then, practical elements of airline and railway integration are discussed including: the type of agreement between the airline and the TOC; the differences in the operational and cultural environment of the rail and air industries and how these are likely to effect the scope for integration; the role of the airport in airline and railway integration; and developments in the ATI, which indicate a decreasing role for H&S operation in the future (section 5.3.2). Since airline and railway integration is largely based on the airline operating H&S system, the future operation of this strategy by airlines is discussed (section 5.3.3).

5.3.1 The cost of providing HST services at Heathrow

The benefits measured in section 4 and the benefits discussed in section 5 must be compared to the cost of constructing a HST link between Heathrow and the CTRL and constructing a HST station at Heathrow. This cost should be compared with the cost of a new runway (and terminal) at Heathrow in line with the discussion in section 5. Below, a ball park figure for the costs of providing the infrastructure for airline and railway integration is provided.

5.3.1.1 The cost of a HST link to Heathrow

The best estimate for the cost of constructing a HST link to Heathrow is the CTRL. The CTRL construction costs are estimated at €69 million per km for the whole project, or €38.5 and €126.9 million per km for section 1 and 2 respectively (CTRL, 2004). The high cost for section 2 is because most of the route (33.6 km out of 39 km) is in a tunnel and because it includes three stations (at St. Pancras, Stratford, and Ebbsfleet).

A dedicated HST link between Heathrow and the CTRL would be similar, in characteristics, to the CTRL section 2. The fact that most of the route passes through densely populated area and the fact that the station at Heathrow should be underground²⁹⁴ means that most of the route would have to be in a tunnel. Using the CTRL section 2 construction costs and assuming the HST link to Heathrow would be 30 km long, then the estimated costs amount

²⁹⁴ See section 5.1.

to a ball park figure of €3.8 billion, including the HST station at Heathrow. Despite the complexity in building a new HST station at Heathrow, for example under the CTA which will have to be around one km long²⁹⁵, the estimate above is reasonable. The HST station at CDG, for example, cost an estimated €280 million (Buchanan and Partners, 1995), and it includes five levels with the lower one accommodating four platforms for HST services and two for the RER services to central Paris (plus two tracks for through services).

The €3.8 billion estimate might actually be considered as an upper limit as explained below. The CTRL is “per kilometre, the most expensive high speed railway to have been constructed anywhere in the world” (CfIT, 2004: 3). Other HST lines around the world were built at substantially lower costs (Figure 15)²⁹⁶. The Madrid – Lerida line in Spain, which opened almost at the same time as section 1 of the CTRL, was 7.6 times less expensive to construct. One of the reasons for the high cost of the CTRL is the substantial sunk costs associated with the fact that analysis, planning and preparatory work were undertaken for a number of possible routes. In more general terms, the high construction costs in the UK are attributed in part to the long period until a project is approved, over-specification at the design stage²⁹⁷, high professional staff costs²⁹⁸, and (perhaps) too strict environmental and safety regulations for railway projects in the UK. In total, the CfIT estimates that changes in the above, which are feasible in the medium term, might result in significant cost savings of up to 20%, and even 25%. If this could be achieved, then the costs of the HST link to Heathrow could be in the range of €2.9-€3.1 billion. There is also a possibility for cost savings following the experience gained in constructing the CTRL, the UK’s first HST line.

Ideally, a ‘through station’ and a dedicated HST line should be built for the benefits, described above, to materialise, but there are other alternatives which are less costly but would provide fewer benefits. One option is a conventional rail link, but with a through rail station at Heathrow that allows for future (HST) services to the North and West²⁹⁹. Several options are available for such a link and the extent to which such a link would use existing lines would determine the cost savings but also the reduction in the capacity available for the

²⁹⁵ To accommodate the long Eurostar type HST. The underground stations at Stratford and Ashford on the CTRL will be 1.1 and 1.7 km respectively.

²⁹⁶ The differences are also attributed to the high ratio of the route requiring tunnels, but also after accounting for this the construction costs of the CTRL are significantly higher than for other routes (CfIT, 2004).

²⁹⁷ For example, “the Channel Tunnel Rail Link has been designed to handle freight, at significant extra cost – but very few paths have been set aside for freight and it is unclear whether even these trains will ever be carried” (CfIT, 2004: 38).

²⁹⁸ These were more than 25% of the costs for the CTRL, but only 2-3% of the costs on the Spanish Madrid-Lerida line.

²⁹⁹ It is important to note that the travel time analysis (section 4.2) considered a relatively modest speed on the Heathrow-CTRL link.

service. AirTrack, a proposal to provide rail access to T5 from the South of London and centres such as Guildford, Woking and Reading (AirTrack Forum, undated) will connect Heathrow with Waterloo³⁰⁰. The project is estimated at €384 million. Perhaps a better option is the proposed Crossrail project, which will allow through rail services between East and West of London and will include a station at Heathrow as well as at Stratford and Ebbsfleet, thus allowing good connection with the CTRL (although this is not planned). However, this line would probably not have the capacity to serve the cross-Channel HST services and there might be technical limitations in using HST services in the Crossrail tunnels. A better alternative might be the North London Line, where already Eurostar trains are running³⁰¹, but also this line will need upgrading to have the capacity to serve the cross-channel HST services.

Figure 15: HST lines construction costs (€millions per km)

Image removed due to third party copyright **image removed due to third party copyright**

Source: CfIT, 2004.

The new rail link from CDG to Paris city centre, a service similar to the Heathrow Express, which is scheduled to open in 2012 is estimated to cost €35 million per km³⁰² but does not include a station at CDG, since this already exists, and it is not clear if it includes a station in Paris (Mott MacDonald, 2003). Accounting for the Heathrow-CTRL route distance translates to an estimate of €1.1 billion.

An orbit rail line around London which runs through London's main airport (generally following the M25 route) is another option. Such a project, or part of it (e.g. south or north circular route), can follow the TGV Jonction example in France which bypasses Paris and

³⁰⁰ Currently the HST services to Paris and Brussels depart from Waterloo, but in the future most and maybe all services from London to Europe will depart from St. Pancras (Brown, 2004).

³⁰¹ When going in or out of Eurostar's maintenance depot.

³⁰² The route is 19.8 km long and includes 9 km of existing track and 10.8 new tracks in tunnel.

provides a connection of the North and South (to Paris) HST line and includes a stop at CDG. Such a route would also provide a fast connection for passengers transferring between the London airports³⁰³.

In summary, a dedicated HST line should ideally provide the connection between the CTRL and Heathrow, with a through HST and conventional rail station at Heathrow, which would allow a future connection of Heathrow with the South-North and West-East HST routes from London, and a connection with the regional rail network. Such a connection, including the station, is estimated to cost around €3.8 billion. A less ideal solution is a conventional rail link between Heathrow and the CTRL, and this is estimated to cost around €1.1 billion. Thus, a ball park figure for airline and railway integration at Heathrow ranges from €1.1 to €3.8 billion.

5.3.1.2 The cost of a new runway at Heathrow

The DfT (2003a) consultation document estimates the cost of constructing a third, 2000m long, runway at Heathrow at £4.2 (€6.3) billion. This estimate includes, in addition to construction costs, maintenance costs for a period of 60 years³⁰⁴, but the majority of the costs can be assumed to relate to the construction of the runway. However, the cost estimate does not include the construction of a new terminal, Terminal 6, which will be required for optimal use of the new runway according to the airport operator.

The DTLR (2002) estimated the capital costs associated with different expansion options of airports in the South East of England. The cost of increasing Heathrow's capacity from 86 mppa³⁰⁵ to 112 mppa (the option that includes one new runway at Heathrow) is €5.97 billion. Table 55 provides a breakdown of the cost of different components, most of which directly relate to the provision of a new runway. Most of these items can be saved if a HST station will replace the new runway. The difference between the estimate in Table 55 and the DfT (2003a) estimate probably reflects the estimated maintenance cost over the 60 years period.

If excluding the 'adds on' category, since a similar component was not considered for the HST link, and the 'other' category (components not related directly to the new runway or terminal), then the cost of a new runway goes down to €3.26 billion, assuming that road and

³⁰³ The idea of a dedicated inter-airport rail service that will connect London's main airports was found not to be viable in a study made by the DETR and SSRA (DETR, 2000a: 62). However, the study mainly considered demand for transfer between airports and not a connection of such a route to a wider HST network.

³⁰⁴ Discounted at 6% per annum.

³⁰⁵ The capacity with T5 assumed in this document (DTLR, 2002).

rail access are necessary if a new runway is built but not if a HST station and link are constructed (these costs are included in the cost of providing the HST link and station).

Table 55: The cost of increasing Heathrow's capacity from 86 to 112 mppa by constructing a third runway (€ million)

Image removed due to third party copyright

Source: DTLR (2002).

5.2.4.3 The capacity provided by a new runway and a new HST station at Heathrow

It is not enough to compare between the cost of a runway and a HST link (and station) at Heathrow; the capacity each of the options will provide must be compared as well.

Heathrow's capacity after the completion of T5 is expected to be 89 mppa or 480,000 ATMs per year. With a new (short) runway it is expected to be 116 mppa or 655,000 ATMs per year, which means that the new runway is expected to provide an additional capacity of 27 mppa or 175,000 ATMs per year.

The capacity of the proposed station at Heathrow is hard to estimate and depends on the type of services it offers. Alternatively, it can be concluded that to allow a fair comparison of costs with the runway, the HST station should provide Heathrow with an additional capacity of 27 mppa. Considering the capacity of a Eurostar train is 766 seats, then 27 mppa equals about 35,250 trains per year, 97 trains per day, or just over five trains per hour (assuming a 05:00-23:00 day). The maximum use of the CTRL (and hence St. Pancras station) is 8 Eurostar trains per hour each way (CTRL, 2004). On the case study route the Channel Tunnel is assumed to be the bottleneck and it has a capacity for six Eurostar trains per hour each way (Le Blond, 2003)³⁰⁶. During the summer of 2004 Eurostar is expected to operate 62 trains per day through the Channel Tunnel, an average of just over five trains per hour (Eurostar, 2004b).

The above indicates that if a comparable station, in capacity, to St. Pancras station would be built at Heathrow it would probably provide more capacity increase than the proposed runway. The cost of such a station was included in the above estimate based on the CTRL construction costs. Furthermore, there is enough capacity on the CTRL and Eurotunnel for the airline passengers.

5.2.4.4. Conclusions

A HST link from Heathrow to the CTRL plus the station at Heathrow are estimated to cost €3.8 billion (or €4.2 billion if including expected modifications for existing terminals³⁰⁷), while the cost of a new runway and a terminal at Heathrow is estimated at €4.4 billion (excluding 'adds on'). The HST estimate is for a dedicated HST line and an underground HST station at Heathrow. It is important to acknowledge that all the estimates show, is that the costs of a new runway and the HST link and station are of the same order of magnitude!

The cost estimate for the HST assumes that the HST station would provide at least an equivalent passenger capacity as the proposed new runway. Furthermore, it is assumed that it would provide a through service and would be a node on the UK's future HST network (or at least on the future South-North HST line which will be connected to the CTRL through the Heathrow link).

BAA, the owner of Heathrow, is expected to bear the full costs of the new runway and terminal. For the HST link (but not the station) the situation is different since the rail

³⁰⁶ Such a high frequency allows relatively easy coordination between HST and aircraft services.

³⁰⁷ Increasing Heathrow's capacity through a HST connection would entail modification of the existing terminals to increase their capacity, which might cost around €622 million, the 'other' category in Table 55.

industry would also benefit from it and therefore must bear some of the costs. “Where a rail project also benefits non-airport rail users the broad aim will be to divide the costs between the airport and [the] SRA” (SRA, 2003b: 11). This might bring the costs associated with a HST link and station to be lower than the cost of the runway making it even more attractive to the ATI. It also means that the HST line South-North becomes more attractive to the rail industry since the ATI would bear some of its costs.

The above cost estimates provide information for a limited comparison between costs and benefits of airline and railway integration. To reach net benefits of €1 billion, from the operation of airline and railway integration on the case study route, would take 23 years³⁰⁸. Including the other routes on which airline and railway integration is expected, and the indirect benefits, it would be much faster to recover the investments in airline and railway integration at Heathrow.

5.3.2 Elements of airline and railway integration in practice

This section aims to portray how airline and railway integration is likely to take place in practice, and especially how it will ‘blend’ into the ATI operation. The assumption here is that the infrastructure needed for airline and railway integration is provided.

One of the messages apparent from the discussion on the wider benefits from airline and railway integration is that ideally, to maximize the benefits, a through HST and conventional rail station should be built at Heathrow. Alternatively, but less ideal, a (conventional) rail link between Heathrow and the CTRL will suffice. In both cases airline and railway integration would be the same, the difference will be in its scope and scale.

Airlines, in general, have two ways to expand their route network: to start their own services on new routes, in competition with services of other airlines, or to cooperate with airlines already operating on these routes, thus eliminating competition with these airlines. In the latter case the airline wanting to expand its services has an array of possibilities for cooperation with the airline already operating on the route. At the two extremes are: code-sharing agreements, where the airlines decide how to divide the supply of services and revenues between them³⁰⁹, and mergers between the airlines (or acquisition of one airline by another). The same options are available for airlines wanting to expand their route network through HST services.

³⁰⁸ Based on €81.8 million net benefits per year from the operation of airline and railway integration on the case study route (section 4.4.2), and assuming a 6% discount rate.

³⁰⁹ In many cases such an agreement would lead to only one airline supplying the service.

Expansion of airline services into the HST network through competition with the TOCs can almost be ruled out. At least in the near future it seems unlikely that the first AiRailLine will be created. The operation of rail and air services is so different that airlines would not be capable of operating rail services and, more important, have no incentive to learn to do it. Acquisition of a TOC by an airline also seems unlikely, probably for the same reasons as mentioned above and in part due to the fact that HST services are often a small part of a TOC's services. However, with companies like Eurostar and Thalys which operate only HST services acquisition is more likely. BA currently owns 10% of Eurostar but has no active role in the management of Eurostar and is considered a 'sleeping partner' (Eurostar, 2004c). The most likely way of cooperation between an airline and a (HST) TOC is a code-share agreement. Such an agreement is the standard for airline and railway integration that already takes place³¹⁰.

Although this form of cooperation requires the least integration between the airline and the TOC at the management level, it still requires full integration at the operation level. The integration between the airline's aircraft services and the TOC's HST services has two main elements: the physical and the cultural elements. In addition, and mainly with respect to the physical integration of services, a third actor, the airport, is involved³¹¹.

The role of the airport in integration³¹² is mainly to provide the infrastructure and the conditions for seamless transfer between the aircraft and the HST services, to the extent that the transfer between an aircraft and a HST should not be less convenient than transfer between two aircraft services of the same airline (or alliance). The most important aspect of the transfer the airport is responsible for is the transfer of passengers and their luggage between the modes. For passengers the distance between the aircraft gate and the HST platform should be minimized and ideally should be overcome by walking (with no shuttle buses or other intermediate modes involved). With respect to luggage, the HST station must be connected to the airport luggage-handling system, which is the case at Frankfurt³¹³. However, the luggage-handling system is required only when passengers can check in and out at the city-centre railway station and this requires the TOC to provide check-in and check-out facilities at the train station and the facilities to carry the luggage on the HST train to and from the airport. Other than that, the level of service offered to passengers on board the HST should resemble the airline service on board the aircraft.

³¹⁰ See section 2.3.

³¹¹ LH's AIRail service is a cooperation between three partners: LH, Deutsche Bahn and Frankfurt airport (LH, 2002).

³¹² See also section 2.3.4.

³¹³ Other than the construction of the HST station this is probably the most expensive element in providing the infrastructure for airline and railway integration at the airport.

From the airline's perspective, matters related to sales, distribution, and information regarding the HST services must be the same as for any aircraft service offered by the airline or one of its partners. This means that through ticketing is available from origin to destination also when the journey involves a transfer to/from a HST, and that at check-in the passenger is allocated a seat on the HST as well. In terms of information, the HST service should be designated a 'flight' number which would appear in any information medium other flights appear in. Likewise, the HST station at the city centre, Gare-du-Nord for example, should be designated an 'airport' code. An important aspect of the above is that the HST journey must appear on all the Computer Reservation Systems (CRS) used by agents or directly by passengers. Finally, the HST services should be recognised in customer loyalty schemes.

It is important to note, regarding the transfer of people and luggage between the aircraft and the HST, that the HST does not have the aircraft's flexibility with respect to departure time. An aircraft can wait five minutes and even more for passengers from connecting flights, and use the next available slot but the HST cannot. This means that a H&S system with many HST services would be much more sensitive to delays. The IARO et al (1998) provide more information on the physical aspects of airline and railway integration.

The integration between the airline aircraft services and the TOC HST services also has a cultural element. Cooperation between the respective industries is usually hampered by the vast differences between the industries (although both 'transport' passengers and goods from A to B). This has led to a very different organisational and operational culture, which is very much influenced by the regulatory framework the industries have been working within during the last few decades. These differences can become a major barrier to airline and railway integration. The lack of reference to airline and railway integration in the UK aviation debate, from both the airlines and the railways, might be the result of these cultural differences.

Perhaps surprisingly, it is LH, probably the world 'champion' of airline and railway integration, which provides the best evidence for the cultural differences between the industries.

RAIL and AIR are both transport modes but...The two modes were born in different centuries...Railway companies operate in the domestic area, most airlines operate far beyond their home country...Railway long haul is very short haul in airline world...The majority of railway customers are students and employees, airline concentrate on business people and vacationers...Railway

companies use their respective national language, the global language of airline is English...Railway companies have a public service obligation, airlines tend to operate where they can make profit...

(Weinert, 2002: 21, emphasis in original text).

The above certainly holds true in many respects, although the differences apply more to conventional railway services and less to (international) HST services. However, more important is that the above quote comes from LH³¹⁴, which was expected to highlight the opportunities, the similarities, and the potential synergies from mode substitution and between the industries, not the opposite. This anecdotal example illustrates the barrier to airline and railway integration imposed by the cultural differences between the industries. In the future, this barrier is expected to be lower as the rail industry increasingly adopts a market and service orientation and learns from the ATI experience. Perhaps, the anecdote indicates LH's experience with airline and railway integration which, if this is the case, is very important to acknowledge.

Even if airlines currently do not see an opportunity in airline and railway integration, the HST has already changed the market on some (European) short haul routes, is (often) winning the competition³¹⁵, and therefore cannot be ignored. In the face of growing competition from HST services on one hand and low cost services on the other, and increasing capacity constraints which hamper H&S operation, airline and railway integration seems to suit mainly network airlines, those airlines which operate a H&S system to some degree.

The ATI proved in the years since deregulation that it is capable to change and adapt to changes in its operational environment and mainly improve its efficiency (Button, 2004). Therefore, in the same way airlines developed the H&S system as a response to deregulation they would probably develop new strategies in light of changing operation conditions that include, amongst other things, internalisation of the environmental externalities they impose (through taxes or other measures) and limited runway capacity. Under such conditions and with the infrastructure for airline and railway integration in place it is expected that the network airlines would integrate rail services into their network.

Suggestions to change the way slots are allocated to airlines at congested airports are likely to have a major effect on the industry. A report for the EC (NERA, 2004) "agrees that a trade in slots would probably result in airports like Heathrow and Gatwick servicing long-haul

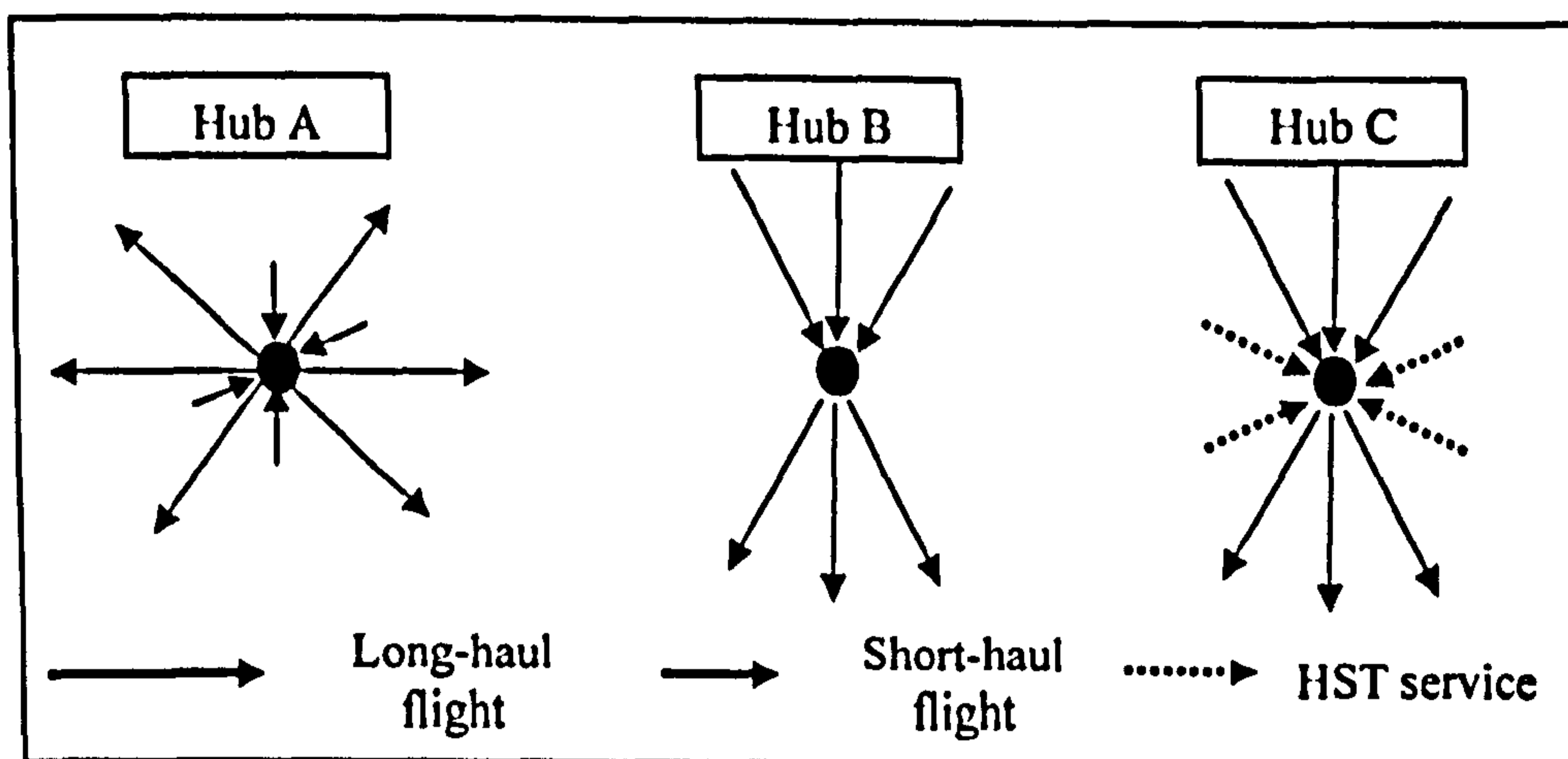
³¹⁴ Mr. Weinert is LH's project manager for intermodal transport.

³¹⁵ See section 5.2.4.1 Table 54.

flights exclusively, leaving short-haul to regional airports” (The Observer, 2004). In this case the attractiveness of airline and railway integration at Heathrow is apparent, certainly in light of the struggle airlines like BA have to preserve their market share on routes like the London-Paris in the face of competition from both HST and low cost airlines. Furthermore, evidence suggests airlines like BA are probably losing on these routes³¹⁶.

One of the assumptions in the model of airline and railway integration developed in this research is that the TOC serves the city-centre to city-centre market, which is currently also served by the airlines. However, the fact that airlines seem to lose (money and market share) in this market and, at the same time, rely on these routes to feed traffic to their (more profitable) long haul routes, means that integration is still an attractive option even if it entails giving up the competition with the TOC on the city-centre to city-centre market. In this case the airline does not ‘waste’ (capacity) resources on markets it loses in but can still retain the feeding traffic.

Figure 16: models of hub airports in a hub & spoke system



Source: based on Doganis and Dennis (1989).

Doganis and Dennis (1989) define two types of H&S models: the ‘hinterland’ and the ‘hourglass’ hubs. The hinterland hub (hub A in Figure 16) feeds short haul connecting traffic to long haul flights, while the hourglass hub (hub B in Figure 16) is operated with flights from one region to points broadly in the opposite direction. The hourglass hub also tends to use aircraft of a similar size, whereas the hinterland hub has aircraft of mixed sizes (Button and Stough, 2000). Doganis (2002b) notes that Heathrow’s pattern of H&S service resembles the hourglass model more, while CDG, for example, adopts the hinterland model. The differences are attributed mainly to the capacity available for the hub airlines at

³¹⁶ “From 1998 onwards European routes began to suffer large losses. As BA’s overall profitability collapsed, three market segments were found to be the main loss-makers – short to long haul transfers in Economy, short-haul point-to-point Economy within Europe and short [haul] to short [haul] transfers” (Doganis, 2002b: 4). A service from Heathrow to Paris serves all of these three markets.

Heathrow and CDG³¹⁷. Under airline and railway integration a hinterland hub model could be adopted even at congested airports, like Heathrow, by the use of HST services (and conventional rail as well) as the feeder services (hub C in Figure 16). This model of H&S operation would enjoy the benefits of the hourglass model (e.g. efficient use of the runways by relatively large aircraft), and the benefits of the hinterland model (e.g. short haul feeder services).

The above scenario depends on airlines continuing H&S operation. Yet, the constant changes undergoing by the ATI means there is some uncertainty regarding the future of H&S operation. This is discussed next.

5.3.3 The future of Hub & Spoke operation

The relatively short history of commercial aviation has proved that this is a very dynamic industry. This characteristic is attributed mainly to the fast technological development and innovation in aircraft production. The fast technological developments lead to constant changes in the operational, organisational and regulatory frameworks of the industry³¹⁸. The changes since the 1980s are mainly attributed to the changes in the regulatory regime governing the industry, namely the deregulation of the US domestic market (in 1978) and the liberalisation of the EU domestic market (effectively from 1997)³¹⁹. One of these changes is the emergence of H&S operation³²⁰ which is at the heart of airline and railway integration.

H&S operation should be considered as a success, giving the large number of transfer passengers at major airports. The majority of these passengers use H&S system of one airline (alliance) or another. However, H&S operation (or its success) has resulted in problems and disbenefits. In short, these can be summarised as follows: a) H&S operation and the dominance of a specific airline (alliance) at a specific airport result in market power for the airline which suppresses competition and drives fares up (e.g. Doganis, 1991); b) it leads to congestion at the hub airport, which increases delays to services; and c) it disadvantages small communities which, as congestion grows, lose access to the hub airports (as happened

³¹⁷ The adoption of the hourglass model at Heathrow means more efficient use of the runways since on average the fleet of aircraft operated from Heathrow is bigger than at CDG.

³¹⁸ Staniland (2003) argues that the increasing drive by airlines to follow commercial objectives in running the airlines, at the time when they were controlled and run by the state, gained momentum due to developments in aircraft technology which resulted in aircraft with higher capacity, speed, and range performances. These technological developments led to lower operating costs and increased competitiveness, which in turn resulted in increasing demand for air services and attractiveness to private investors, thus reducing the need for state support. Nowadays technological developments seem to aim for more economic operation, and in the future, perhaps, for more environmentally efficient operation.

³¹⁹ In principle, different jargon for the same thing.

³²⁰ See section 2.1.1.

at Heathrow). These disbenefits can be contested since H&S operation by its nature allows services for destinations which were otherwise not served from the hub airport; it leads to less congestion at the network level compared with a situation where all destinations are served by direct services between them; and, competition between hubs and different airline networks potentially keeps fares down³²¹. Nevertheless, it seems that at some airports H&S operation certainly leads to some or all of the above disbenefits.

The emergence of low cost airlines in the US and in Europe provides an alternative to H&S airlines, and the associated disbenefits, for many passengers. The low cost airlines offer passengers: point-to-point services that bypass the hubs, and therefore usually are faster and more reliable, at much lower fares, and (often) at the same or higher frequency. In turn, the relatively low fares together with the general trend in increased demand have generated new demand for air services. This means that more city pairs can generate enough demand to support direct services between them at a time when services to these cities through the hub airports are effected by lack of capacity at these airports. Thus, the reliance on the hub airport is decreasing in many markets.

The weak financial position of many network carriers in 2001 meant that the impact of the September 11 terrorist attack on airline services drove many of them onto the edge of bankruptcy (Nolan et al, 2004)³²². During this time the low cost sector seemed to thrive, showing profits and increase in services and capacity (on both new and existing routes)³²³, in part benefiting from the crisis of the network carriers as price sensitive passengers were lured to low cost alternatives (Franke, 2004). The above might indicate that the H&S model is not viable anymore (see also Tretheway, 2004),

However, this seems unlikely as “it would seem impossible for a reasonable intercontinental destination portfolio to be served without a hub” (ibid) and there would never be enough demand for direct services between all major cities of the world. Furthermore, the low cost model could probably not be replicated for the long haul market as well. Instead, the crisis of the network airlines and the success of the low cost airlines might serve as a catalyst for the former to restructure its operation and “break free of the vicious cycle of connectivity and complexity” (ibid: 19, see below).

³²¹ See for example “debunking some common myths about airport hubs” (Button, 2002).

³²² Indeed, it took some more time before airlines such as Swissair and Sabena collapsed and other sought bankruptcy protection such as US-Airways and United-Airlines.

³²³ For example, referring to 2002, “chief of European low cost operator, Ryanair, told a news conference in Milan today that his company was still on track to post net profits of EUR230 million (USD\$243.2 million) this year... He was speaking at the budget carrier's new base at Milan Bergamo Airport” (AirWise News, 2003e).

The prediction is that H&S operation would continue to be the strategy for many (large) airlines, while for others the low cost model will be more appropriate. Furthermore, it seems that in the future, medium size airlines, the likes of Sabena and Swissair, would have to either join one of the airline alliances, and fit their network to the needs of the alliance and downsize their hub operation³²⁴, or transform into a low cost airline focusing on point-to-point regional routes. For some airlines outside the US and the EU the protection by the country, i.e. for flag carriers, might allow them to continue business as usual for some (limited) time³²⁵.

Consolidation within the network airlines, most likely through expansion of airline alliances, is expected as a consequence of the reduced market share of these airlines, a share lost to the low cost airlines (Tretheway, 2004). Already, it seems, the industry, apart from the low cost airlines, is heading towards a future of a few mega carriers operating under the brand name of an alliance. The formation of these mega airlines/alliances is still restricted by the regulation framework governing international air services (Doganis, 2001), but the pressure to extend the open sky policy to the rest of the world might mean that the way towards full mergers between airlines, which will replace the complicated alliance agreements, is opening. This is still relatively far from happening, but in the short term an open skies agreement between the US and the EU seems realistic³²⁶.

One of the principles of H&S operation is that it offers high connectivity at the hub airport in order to lure passengers to transfer through a certain hub and not another³²⁷, but this comes at a high cost. To offer high connectivity, airlines attempt to schedule their services into waves of arrivals and then departures of services to/from the hub airport within a short period of time, and this leads to inefficient use of airport infrastructure and airline resources (Dennis, 2001). To lower their costs and better position themselves in the competition with the low cost airlines, the H&S airlines must make the trade off between connectivity and productivity. "A certain reduction of connectivity would potentially unleash cost potentials through increased airside productivity, landside productivity, and punctuality" (Franke, 2004: 20). American Airlines took such a step and adopted a:

³²⁴ "The best example of a non-sustainable hub system is that of STAR group with hubs in Frankfurt, Copenhagen, Munich, Vienna and Warsaw. Only one or two of these can survive as enlarged hubs" (Doganis, 2002b: 7).

³²⁵ An example can be the Israeli flag carrier El-Al. However, the on-going privatization of the company and the likely replacement of the Israeli bilateral agreements with individual European countries by a collective agreement with the EU might end this 'protection'.

³²⁶ At the time of completing the thesis such talks were underway with the aim to sign an open sky deal at an EU-US summit in Dublin during June, 2004 (AirWise News, 2004a). This later failed to happen, but nevertheless such a deal seems plausible in the near future (AirWise News, 2004b).

³²⁷ This means offering passengers as many connecting services to as many destinations as possible within a short period of time from their arrival to the hub airport.

'continuous' or 'rolling' hub in which aircraft arrive and depart throughout the day rather than being concentrated in a series of coupled arrival and departures banks. The number of flights remains the same, but with the workload more evenly distributed, aircraft, staffing and facility demands are lessened at a time when every penny saved is one less that has to be earned from an increasingly parsimonious travelling public

(Flint, 2002: 22).

BA, it seems, was forced into such an operation³²⁸ by the lack of capacity at Heathrow and specifically the lack to control high enough percentage of the slots at Heathrow (Doganis, 2002b).

In doing the trade off between connectivity and productivity Franke (2004) suggests that rather than to completely adopt American Airlines' model, airlines should prioritise the connections in a way that high-yield traffic should be optimized to connectivity and low-yield traffic to productivity. Alternatively, dominance to East-West traffic over South-North traffic, or intercontinental traffic over continental traffic should be given, depending on if a certain market is dominated at the respective hub. A better alternative for some airlines is to shift, where possible, services to the HST, increasing the frequency on the remaining aircraft and thus increase connectivity without added (airside operation) complexity.

For BA, this would mean concentrating on the East-West long haul traffic and optimizing connectivity while emphasizing productivity with respect to the short haul market and serving some of the short haul markets by rail services. Using rail service would allow BA to change its focus within the short haul market to the domestic market. Despite the limitations BA faces in adopting a full H&S strategy at Heathrow, it is unlikely to completely abandon it. However, with only two runways (and even with a third short runway) at Heathrow, BA, or any other airline based at Heathrow, would not be able to adopt a full H&S operation and would probably have to concentrate on long haul operation across the Atlantic where it has a relative advantage over airlines operating from other hubs. An expected boost to Heathrow comes from the development and, soon the launch, of the new A380 capable of carrying up to 800 passengers. This aircraft can significantly increase Heathrow's passenger capacity without any increase in runway capacity. In a way it would be ideal for a company like BA to optimize its H&S operation increasing the passenger throughput despite limited runway capacity. At congested airports where long-haul traffic plays a major role, an H&S operation

³²⁸ Rietveld and Brons (2001) developed a measure for the quality of co-ordination of timetables at hub airports (α). They found that for Heathrow $\alpha=0.64$ when $\alpha=0.5$ means there is no co-ordination of timetables.

based on A380s on one hand and HST services on the other seems to be the optimum. To date (June 2004) 129 aircraft of this model have been ordered by 11 airlines (Airbus, 2004), many of them operate to/from Heathrow and expect to use the aircraft on services to/from Heathrow³²⁹ (e.g. Virgin Atlantic, Singapore Airlines, Emirates, Qantas, Korean Air, and Malaysian Airlines). Perhaps surprisingly, BA is not yet an Airbus customer for this aircraft³³⁰.

³²⁹ "BAA estimate it [the A380] will account for one in every eight flights at the airport by 2016...[and it] could enable 10 million more passengers to fly to and from Heathrow with no increase in flights" (AirWise, 2004d).

³³⁰ However, "BAA assume[s] British Airways will be using the A380 aircraft. BA...has said it is in no rush to make a decision on purchasing the A380" (AirWise, 2004d). AF and LH, BA's main competitors have ordered the A380.

5.4 Conclusions

Section 5 provided evidence that there are many more benefits from airline and railway integration in addition to the direct net benefits evaluated and quantified in section 4. The evaluation of airline and railway integration in sections 4 and 5 provided enough evidence to put forward the case for airline and railway integration, in general and in the UK. Hence, the research can come to an end at this point, although it is recognised that further research must be carried out. Based on sections 4 and 5, conclusions can be drawn and their implications for future mode substitution can be discussed. This is done in section 6. Below, the main findings from the evaluation of airline and railway integration in a wider perspective are summarised.

The indirect benefits from airline and railway integration, part of which are more the result of providing a high capacity railway station at Heathrow, with HST and conventional through services, are summarised in Table 56³³¹. The benefits refer specifically to Heathrow and the UK but in general indicate the potential for benefits elsewhere when high quality HST and conventional rail infrastructure are provided at an airport.

Other than the high investments required for airline and railway integration no significant disbenefits were recognized. Two potential disbenefits, if they exist, will be borne by society in general and the passengers. First, if the freed slots would be replaced by other flights, overall increasing the airport capacity, then environmental pollution will probably increase. However, if Heathrow's capacity is increased through a HST link and not through a new runway, then a reduction in environmental pollution is expected. Second, airline and railway integration might result in reduced competition, on routes where it takes place, leading to a lower level of service and higher fares for passengers. However, if integration takes place on the case study route, the integrated airline and railway service would still compete with other services on the origin-destination market that fly directly or through other hubs. On the city-centre to city-centre route (e.g. London-Paris), the integrated service will remain in competition with the low cost airlines. Therefore, and overall, reduced competition does not seem to be a major disbenefit from airline and railway integration.

³³¹ For convenience, the indirect benefits are divided between the different beneficiaries, but are very often 'enjoyed' by more than one beneficiary. Especially for the operators (airlines, airports, railways) benefits to one does not offset, but rather enhance, benefits to the other.

Table 56: The main indirect benefits from airline and railway integration

Beneficiary	Benefits	Comments
Airlines	Additional capacity	Even at congested airports.
	Freed slots	For the use of other services (or for sale).
	Strategic advantages	Improved network economics (more services to more destinations). Improved H&S operation (a distinguishing feature from the low cost carriers). Access to domestic market (for foreign airlines).
Airports	Increased connectivity	Improved competitiveness of the (Heathrow) airport, especially as a hub airport, against its main rivals (in CDG, Frankfurt and Schiphol).
	Increased catchment area	
	Consolidation of terminal capacity	
	Improved accessibility	By public transport means. One of the targets set at Heathrow.
	Reduced LAP	From both aircraft and cars. A real benefit at Heathrow since operation is likely to be limited by high NOx levels.
	Improved prestige / status	Matching the facilities which already exist at CDG, Frankfurt and Schiphol.
Railways	Increase in demand	Mainly on profitable markets as a result of a) services shifted from the aircraft b) shift from access journeys by other modes c) through induced demand.
	Cooperation/links with the ATI	Opportunities for cultural interaction to improve the railways' service and market oriented operation.
(UK) Society	Economic benefits	By preserving and enhancing the competitiveness of Heathrow (according to the government).
	Accessibility benefits	Improved access to Heathrow's high level of service and range of destinations mainly from the regions. Improved public transport access to the airport.
	Integrated and sustainable transport system	Contribution towards fulfilling the government transport policy aims and targets.
	Environmental benefits (?)	From increased share of access by public transport, in addition to the benefits from mode substitution. (These benefits are probably offset if short haul flights are replaced by long haul flights).
	Saved investments (?)	Not expected!
Passengers	Passengers are expected to benefit directly and indirectly from all the benefits listed above. None of them is expected to disbenefit passengers.	

The cost of the HST link and station at Heathrow was found to be of the same magnitude as the cost of a new runway. However, these costs are expected to be split between the private (air) and the public (rail) sectors benefiting both. Therefore, BAA, the owner and operator of Heathrow which is expected to fully pay for a new runway, would enjoy comparable benefits from a HST link and station but can expect to pay less for it. The railway industry would

benefit from a private sector contribution to the investments in the future HST network in the UK, starting with a South-North line³³². In addition, the nature of a HST link to Heathrow as part of a future HST network in the UK means that the EU can also be expected to contribute, further reducing the burden on the air and rail industries.

The indirect benefits from airline and railway integration were not quantified, but nevertheless, such benefits are expected and they might be even more significant than the direct benefits. In any case, they significantly strengthen the case for airline and railway integration. It is important to note that even if investment in new runways is not replaced by a HST link and station, benefits from the latter would still exist and might on their own justify the investment. Furthermore, if investments in rail infrastructure at the airport will not replace investments in a new runway, it will still delay them.

Other than the wider benefits from airline and railway integration, it was found that despite the undergoing changes in the ATI there will still be scope for integration in the future. Although it seems that the rise of the low cost airline sector will continue, it would not be able to fully replace the services provided by the network carriers, suggesting H&S operation would be employed by the major airlines in the future. The diminishing benefits from H&S operation, associated mainly with congestion at major airports, are not expected to limit the use of H&S operation but to change the way it is applied. One of the most beneficial changes envisaged are the use of HST and rail services as part of an airline H&S operation. Thus, the case for airline and railway integration is stronger when considering the limitations in current H&S operation.

³³² One of the recommendations made by the CfIT study on HSTs (CIT, 2004) is that such a line should be built in stages starting from the South. The CTRL-Heathrow section could be the first stage.

6. Discussion and conclusions

The research conclusions are divided into three parts. First, the empirical results are discussed considering the evaluation of both the direct and the indirect benefits and from this, policy aspects are highlighted and recommendations are made (section 6.1). Second, the methodological contribution of the research is discussed, including the use of the evaluation results in the decision making process (section 6.2). Finally, the empirical conclusions and the methodological conclusions are combined to provide a summary recommendation for the UK, suggestions on how this research should be used in making a decision on airline and railway integration, and a prediction for the development of airline and railway integration in the UK and in general. The section ends with recommendations for further research (section 6.3).

6.1 The empirical and policy aspects of airline and railway integration - conclusions

6.1.1 The results

This research tested a new approach to aircraft and HST substitution, one of airline and railway integration. In this approach, the airline substitutes the aircraft service with a HST service which is operated by the TOC. This HST service begins at the airport, where the airline operates a H&S system, and is integrated with the rest of the airline routes.

The focus of the research was an empirical evaluation of this model of integration and the benefits it would bring to airlines, passengers and society. The nature of the evaluation was a comparison between an aircraft journey and a HST journey, based on the model of airline and railway integration, between Heathrow airport and Paris (see Figure 7). The results were described in section 4.

Following the analysis, it can be concluded with confidence that airlines are likely to incur OC losses, and society is likely to benefit from a reduction in environmental impacts. Most of the environmental benefits, however, would be from reduction in climate change, which would not necessarily be felt by local people in the UK or France. Reductions in LAP would be less significant in terms of overall benefits but would be more significant locally. Despite the uncertainty associated with measuring environmental effects in monetary units, the conclusion that environmental benefits are expected is robust.

By far the largest direct benefits are travel time savings for which there is the least confidence in the results; first, because the actual time savings depend on several assumptions, and second, due to the difficulty in assigning a monetary value to the travel time savings. Still, travel time savings are expected and in addition, passengers would enjoy better travelling conditions, which implies that even if no travel time savings were gained passengers would still benefit.

Although environmental benefits were considered to be the main reason, from a policy perspective, for airline and railway integration they do not seem to justify it if current cost estimates of the damage from LAP and climate change are accepted. However, there is no doubt that mode substitution under airline and railway integration would, overall, result in more environmental benefits than mode substitution, which leads to competition between the modes.

The lower LF for HST services (assumed at 50%) compared with the aircraft (70%) is considered a disadvantage as it reflects an inefficient use of capacity, and this was not accounted for since the analysis was based on seat units. Accounting for it within the CBA would reduce the benefits substantially. However, it would conceal one of the benefits from airline and railway integration and that is that it can increase the HST service average LF and the fact that the airlines can fill those seats at a less than average cost price.

Based on the evaluation of the operation of airline and railway integration, the following conclusion was reached:

On HST routes of under 800 km in length, where the HST route is not more than 20% longer than the aircraft route, and the average HST speed along the route is at least 200 kph, the operation of airline and railway integration is beneficial to airlines, passengers, and society.

Following the above definition for beneficial airline and railway integration and considering current destinations served from Heathrow, five routes were identified. These routes consume almost 10% of Heathrow's yearly ATM capacity, which represents the potential to free runway capacity at Heathrow through mode substitution. Airline and railway integration on all these routes could bring benefits in the range of €200 million a year and even more³³³. There are other routes where airline and railway integration is practical, especially if the aim is to free runway capacity, but 'integration' on these routes would lead to travel time losses and therefore net losses.

Other than travel time savings, OC savings and reductions in environmental impact, there were many indirect benefits from airline and railway integration. These were considered in section 5 and were evaluated mainly in a qualitative manner. While direct benefits were at the route level and of international nature, the indirect benefits were mainly at the (Heathrow) airport level and the (UK) national level.

The model of airline and railway integration assumed a HST station at the airport that is located in relative proximity to the airport terminals to allow short and seamless transfer between the aircraft and the HST. At Heathrow, this would require a HST station under the CTA at a substantial cost of a few billion €. The investment means that if such a station was built it should also serve the conventional rail network, and it should be built to allow through services to maximise the connections with conventional and (future) HST networks.

³³³ Considering the level of operation on these routes and the fact that on all routes, except the route to Paris, airlines would not bear OC losses.

Consequently, many of the indirect benefits are associated with the provision of such good rail services at Heathrow and not with airline and railway integration.

What is important is that the costs of such a station, including a HST link between Heathrow and the CTRL (to allow airline and railway integration at least on the case study route) is comparable to the cost of constructing a third runway at Heathrow, which would provide benefits similar to the benefits from airline and railway integration, but at much higher environmental costs and without the benefits of better rail access to Heathrow. Furthermore, airline and railway integration allows for the sharing of the costs between the private (aviation) sector and public (rail) sector.

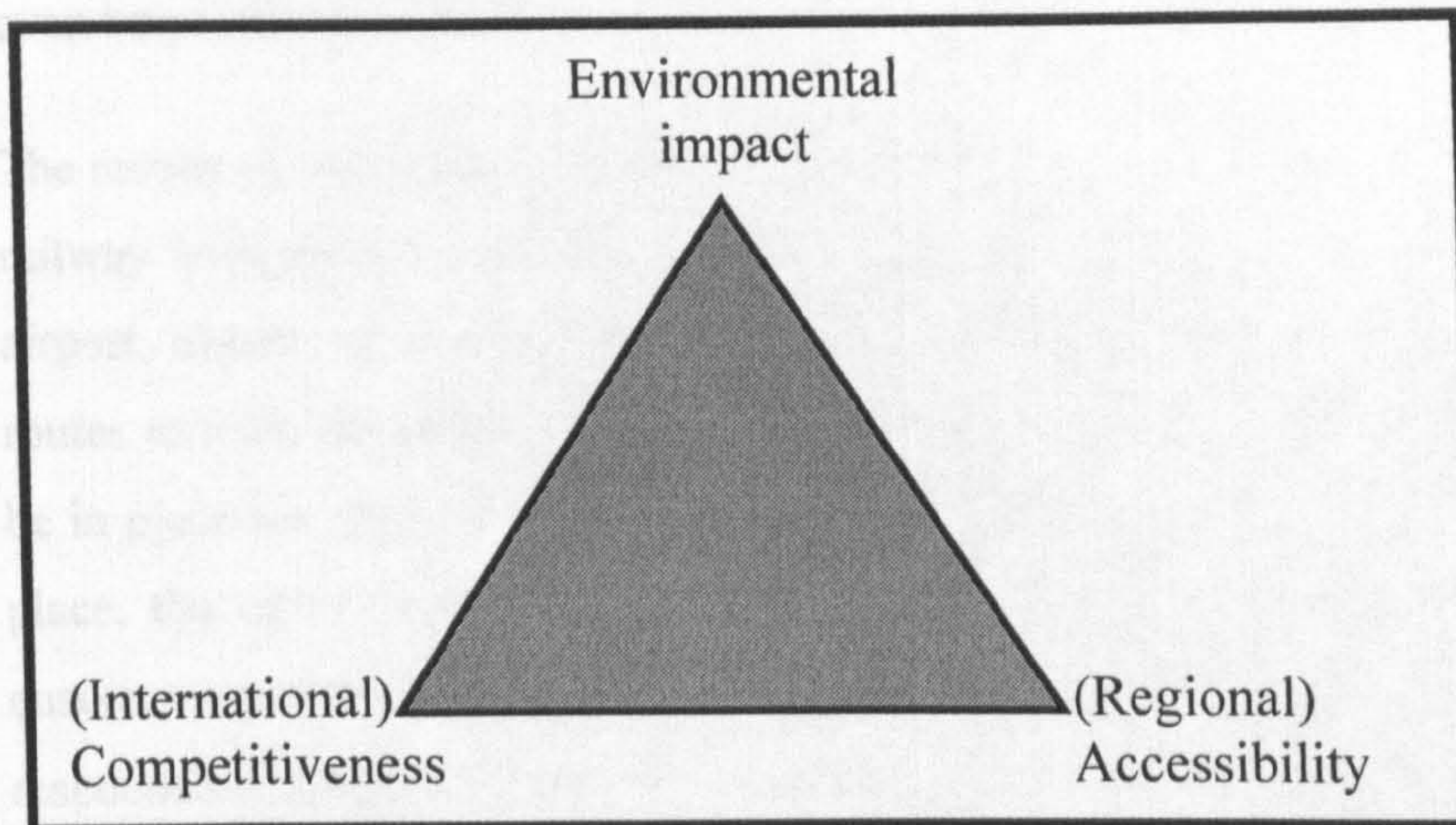
Considering a 'through station' at Heathrow, it was concluded that all private sector stakeholders, namely airlines, airport owner, and the railways, would benefit from airline and railway integration and that this is a better way, economically and environmentally, to achieve the policy targets for the aviation and railway sectors in the UK. These benefits were not quantified but are expected to be as, and maybe even more, significant than the direct benefits, certainly if excluding 'international' benefits³³⁴.

When considering airline and railway integration in a wider perspective, an increase in environmental impacts is possible if the freed slots are replaced by other flights, overall increasing the airport capacity and level of operation. However, if airport capacity is increased through HST services instead of by additional aircraft services, then a reduction in environmental pollution is expected. Hence, airline and railway integration would not lead to environmental benefits under all conditions, and it is not a magical substitution for management of demand for air services.

The benefits from airline and railway integration can be summarised as follows. The aims of the UK air transport policy with regard to Heathrow are mainly three fold: to preserve its international competitive position as a transfer/hub airport, increase accessibility to it from the (UK) regions, and limit/reduce its environmental impact. These are irreconcilable aims as illustrated in Figure 17. Under a given (runway) capacity, and when the airport reached this capacity, a trade-off between flights from the region (accessibility) and international flights (competitiveness as a transfer hub) must be made. If capacity is increased to meet both of these aims, the environmental impact will increase. However, the use of HST, as suggested in this research, provides reconciliation between the conflicting policy aims.

³³⁴ See section 6.2.

Figure 17: The irreconcilable policy targets for Heathrow



6.1.2 The main implications of the results

The results of the evaluation support the case for airline and railway integration as the preferred model for aircraft and HST substitution. Simply encouraging mode substitution where passengers also substitute the airline with the TOC might be counterproductive from society's perspective because airlines would not stop flying on these routes and hence actual mode substitution would be limited. Airlines would continue to fly since it seems there would always be a demand for short haul flights to hub airports to connect with other flights. Perhaps the fact that airlines can still maintain some market share on the case study route is the best evidence of this.

The implications of airline and railway integration are that the airline gives up the city-centre to city-centre market (on which it probably already has a relatively small market share), but retains the transfer traffic market. The airline, however, serves this market using HST services and thus releases valuable runway capacity and stops competing with the TOC. For this, the current HST service from London to Paris is extended to Heathrow.

The integration of the airline and the TOC services means that such an agreement could be beneficial, even if the airline's demand for HST services is relatively small. It also means that without the agreement with the TOC, the airline could not justify mode substitution, i.e. operate its own HST services to substitute the aircraft.

For airlines not operating a network of services with connections between them, airline and railway integration does not seem to provide an attractive option. These airlines if they cannot compete with the HST have no incentive to continue operating on the route. Often,

such airlines are able to successfully compete with the HST, retain some market share and even be profitable, often by adopting the low-cost model, for example Easy Jet.

The results of the evaluation showed that the private sector has a lot to gain from airline and railway integration, and especially airlines operating a network of services from a hub airport, owners of hub airports, and TOCs which are likely to operate (HST) services on routes to/from the airport. However, these private sector actors require the infrastructure to be in place for them to support airline and railway integration. Once the infrastructure is in place, the other elements of airline and railway integration, and mainly the elements to ensure a seamless transfer between the modes, would be supplied and taken care of by the respective operators. This includes shared ticketing for the modes and integration of the HST services into the flight information systems (the airports' and the airlines').

The decision to provide the infrastructure, however, can only be made at the policy makers' level, and it is up to policy makers to promote airline and railway integration as well as making it more attractive to the ATI.

In more general terms, the evaluation added another consideration to account for when examining if certain routes would be suitable for mode substitution other than the route distance. That is the ratio between the aircraft and the HST route distance, which has a significant effect on the potential benefits from airline and railway integration.

Another important implication of the results is that travel time benefits can occur even when there are no travel time savings due to better travel conditions that allow productive/beneficial use of the travel time mainly through uninterrupted journey.

Finally, the results provide a good indication for the potential benefits from airline and railway integration on other routes³³⁵.

6.1.3 Policy recommendations

The UK Government states that it is “committed to ensuring that the long-term development of aviation is sustainable. This will mean striking a balance between the social and economic benefits of air travel and the environmental effects of any new development” (DfT, 2003a: 8). Airline and railway integration with its wider benefits is the best way to ‘strike the balance’ with respect to the ATI, as was illustrated in Figure 17.

³³⁵ Considering the Beijing-Shanghai route for example (Aircraft route: 1185 km, HST/aircraft route ratio: 1.1 (Table 4)), OC savings and reduced environmental impact can be expected, but no travel time savings.

However, aircraft and HST substitution through airline and railway integration is not the panacea for meeting forecast growth in demand for air travel. The debate on whether the benefits from meeting the demand exceed the (environmental) costs will continue even if airline and railway integration is adopted, and this debate is outside the scope of this research. For the same reason, this research does not deal with the use of the freed slots following mode substitution. Whatever the outcome of this debate, the role of the HST in the ATI operation, through substituting the aircraft and the car (to access the airport), remains considerable. Whether the aim is to preserve Heathrow's position as a hub airport or promoting access to Heathrow from the regions, the HST can fulfil both roles by serving Paris, Brussels, Manchester, Newcastle, Bristol and many other cities.

The same debate would determine the extent to which 10% of Heathrow's runway capacity, which could be released by airline and railway integration, is meaningful, and if it equals one, two or more years of growth in demand for air travel. However, there is no doubt that 10% of Heathrow's current runway capacity is significant, as indicated by the value of a slot. Furthermore, there are many other benefits from airline and railway integration, all significant, which can not be met through extra runway capacity.

In contrast, the question where demand should be met is closely related to airline and railway integration since demand for air services should be met, if this is the chosen policy, at the airport most suitable for airline and railway integration.

In the UK, Heathrow is the natural choice for expansion given the government aim to preserve its position. However, the government recommendations are for a new runway to be built at Stansted first (DfT, 2003b) and, in the long term, even with one new runway Heathrow would not have the number of runways required for a H&S operation, an option that is available for Stansted. However, as long as Heathrow remains in operation, Stansted is unlikely to become a hub (Doganis, 2002b; DfT, 2003b). With the decision to construct T5, Heathrow's fate seems secure.

Related to the same matter is the question of whether supply should be concentrated or dispersed between the London airports. The aims to keep London's competitive position as a hub airport, to allow access from the regions to the range of international destinations served from London, and to maximise public transport access to airports, all suggest concentration should be preferred. Such concentration would also improve the scope for the direct and indirect benefits from airline and railway integration, and thus airline and railway integration. Accordingly, this research supports concentration of capacity in one London airport also at a national level, meaning that demand should not be shifted to the regional

airports, but should be funnelled through the (HST) rail network to the main airports and mainly the main London airport. This has the potential to reduce the number of flights, reduce the use of competing hubs by UK passengers, and increase the economics of scope at the main (London) airport/s. Such a policy also has an environmental element, related to the environmental benefits from H&S operation compared with many more direct flights, but this effect is not clear. The fact that much of the feeding traffic in the H&S system is expected by rail might shift the balance towards environmental benefits from H&S operation.

Because it seems that the decision on London's main airport has already been made and Heathrow was chosen³³⁶, then Heathrow's capacity should be increased by providing a HST link to the CTRL, and a rail station at Heathrow for both HST and conventional rail services, to begin with. This link should form the first stage in a future South-North HST line. Further in the future, a West-East HST line should also be considered, originating in the East from Heathrow. This should come at the expense of the proposed third runway at Heathrow. Despite the choice of Heathrow as the UK's main airport it will not benefit from increased capacity in the near future due to environmental constraints imposed on the UK by the EU (NOx emission) regulations.

The above suggestion is in line with the recognition that as airports grow they must shift attention to their landside and access capacity components before further airside growth is sought. This specifically holds for Heathrow where, it seems, this aspect of the airport has been neglected, unlike the situation at CDG, Schiphol and Frankfurt airports.

It was repeatedly mentioned in this research that in a deregulated ATI it is up to the airlines to choose their strategies and actions. But nevertheless, airlines, and the ATI in general, still operate within a regulatory framework that is imposed on them. The actions taken by the ATI are very much influenced by the policies decided by the government and the extent to which the ATI can influence these policies. Therefore, the fact that airline and railway integration is currently not on the agenda in the UK, reflects a lack of interest from the industry. Furthermore, following the proposals of Terminals 4 and 5 at Heathrow and the second runway at Manchester airport, the ATI 'feels' it can influence policies towards provision of extra runway capacity, and the White Paper is perhaps the best evidence for the success of this strategy.

³³⁶ Heathrow's limited potential for expansion, the very bad design and location of its terminals, and its proximity to densely populated areas all suggest that Stansted would probably better serve as the UK's main airport, replacing Heathrow which, over a process of several years, could be shut down.

Therefore, the first step towards airline and railway integration is to recognise, at the policy level, its benefits to the UK's air and rail industries and accordingly put on the agenda plans to connect Heathrow with the CTRL and to construct a high capacity rail station at Heathrow. Such plans, which would aim at airline and railway integration, should be part of a wider plan for the construction of a new HST line across the UK. In addition to the infrastructure, policies can promote better integration between aircraft and rail services by other means as part of meeting different policy aims, including reduction in the environmental burden imposed by the ATI operation, and mainly a reduction in air pollution. The aim should be to alter airlines' behaviour and to lead to reduced frequency (compensated for by using larger aircraft) and a significant increase in airline and railway integration. A substantial increase in landing charges, for example, could achieve such goals. In addition to the above, adopting airline and railway integration at the policy level is a real step towards integration of transport modes. Following airline and railway integration this can then be applied to other (public transport) modes. Furthermore, airline and railway integration emphasises that international (air) travel should not be looked at in isolation from domestic travel (by other modes).

The above discussion applies almost equally to many other airports and countries, which is an important contribution of this research. The debate on airport expansion takes place almost all over the world and is believed to lack any reference to the potential of airline and railway integration and other benefits from greater use of the railways in the ATI. This is more surprising in circumstances where plans for HST lines or network already exist or are under construction. A good example is China, where currently a HST line is under construction from Beijing to Shanghai side by side with plans for a new airport (AirWise News, 2003c). Perhaps more alarming is the lack of action to promote airline and railway integration by the EU, for example as part of the TEN projects, although such action would be in line with EU policies.

In conclusion, from a policy perspective, this research concludes that mode substitution should be promoted through airline and railway integration, i.e. as an opportunity and not as a threat to airlines. Such recognition on the part of policy makers must be part of recognising the wider opportunities which lie in closer cooperation between the rail and air industries and in connecting the air and rail networks, and it should lead to recognising that the air and rail industries do not operate in complete separation from one another.

It is mainly the public sector which needs to promote airline and railway integration, although the final decision is the airline's (depending on an agreement with the TOC). It is assumed that given the conditions faced by the ATI, especially at airports such as Heathrow,

once the infrastructure is provided, airlines, airports, and TOCs will find ways to cooperate and integrate their services. This is evident at CDG, Schiphol, and especially at Frankfurt. The latter might suggest that the UK ATI is 'losing the competition' with the above airports, as noted by many, because it fails to learn from the experience gained at these airports.

Finally, the research conclusions demonstrate the strength of empirically led policy. It is the extensive empirical analysis that allows confidence in the policy recommendations suggested.

6.2 Airline and railway integration - the methodological aspect

Evaluation practices have a long history, and in this research were used as the main research tool to empirically examine airline and railway integration. It was found that despite the long history and progress in developing evaluation methodologies, there are still limitations in using them, especially as the basis for any decision regarding airline and railway integration. This provided evidence for the challenges in identifying and measuring the different impacts of changes to the transportation system, more than it provided evidence for the limitation of current practices. However, it is through experience gained in using current practices that methodologies can be improved, and this was one of the aims of this research.

6.2.1 Airline and railway integration – an evaluation framework

The advantages of using CBA were outlined in section 3.2 and throughout the empirical analysis. Using monetary units to quantify the benefits from airline and railway integration was the only way to compare the benefits of travel time savings with environmental benefits, for example. It is these features of the CBA that lead most appraisals of transportation projects to use, in one way or another, CBA. However, the methodological problems associated with the translation of any effect to monetary units, evident in this research, result in the wider use of MCA where in most cases the CBA is embedded within it. An example is the New Approach to Appraisal (NATA) in the UK. This meant that the aim of the evaluation shifted from evaluating by how much one mode, project, or policy is better than another to just trying to conclude with high certainty which is better, leaving the ‘by how much’ question for the financial analysis (FA).

Yet, the experience gained in this research from using CBA and MCA showed that there is no good substitute for the monetary units when considering different effects that need to be summed together. There is also no good substitute for monetary units when trying to appreciate if the impacts are significant and even more when trying to communicate results to someone who was not closely involved with the evaluation. However, this does not remove the fundamental limitations in, for example, putting a monetary unit on CO₂ emission; on the contrary, it only leads to temptation to conceal or ignore these limitations.

The approach taken in this research, and suggested as a better practice, is to use the CBA and MCA results side by side. That is, for each category of effects/benefits that is evaluated, a MCA type of evaluation should be made, including as many parameters as practical, and

then also adding a monetary parameter. The robustness and extent to which the monetary estimate can be used and relied on is then estimated by comparing it with the results of the MCA. For example, in this research the monetary benefits from reduced climate change were similar to the proportion of benefits when measured in CO₂ equivalent units, and this increased the robustness of using the monetary analysis. To increase transparency, the MCA results must be shown as part of the evaluation output.

Accordingly, this research supports the use of monetary evaluation of environmental impacts, in line with the DfT recommendations, but only alongside evaluation in other units. Supporting the CBA with the results of the MCA would greatly improve the way the results are interpreted and the extent to which the uncertainty associated with them is understood and accounted for. Still, even presentation of the results in this way cannot replace the need to clearly spell out the assumptions made and the main limitations, such as noting that there is still great uncertainty in converting NO_x emission to CO₂ units. What this means is that the evaluation would always remain subjective since it depends on the assumptions made. The implications of this with regard to how the evaluation is used in the decision making process are discussed below (section 6.2.2).

Even if subjectivity cannot be removed from the evaluation process, evaluation procedures and practices can be improved based on experience gained and changes in the requirements of the evaluation³³⁷. Such improvements could improve the quality of the results and would assist decision makers. Such improvements are suggested below.

The main methodological challenge in this research was the fact that an aircraft was compared with a HST, and at the same time the HST was used together with the aircraft on the same journey. The second attribute, the multi-modal journey, was a challenge in converting travel time savings to VTTS. The first attribute, the challenge in multi-modal evaluation, affected the whole analysis and had to be addressed at the outset. The solution to this challenge was to find a common denominator for both modes which would bridge their inherent differences. The relevant differences between the aircraft and HST in this research were the capacity of each mode and the distance it covered on the case study route. Hence, the use of seat per route units for any effect/benefit evaluated was the way to compare apples and oranges in a 'like with like' manner. The use of a seat, rather than a passenger,

³³⁷ For example, the need to include environmental impacts in the evaluation is relatively new.

meant that the results were not influenced by assumptions on LF³³⁸ and the factors influencing the LF. Yet, the results allow differences in LF to be accounted for.

The concept of airline and railway integration was based on the fact that the airline and the TOC 'share' the HST service, which suggests that perhaps not all of the impacts from the HST journey should be borne by the airline. The aircraft journey, on the other hand, was solely an airline service. This imposed another methodological challenge. If the TOC does not have to add one seat to the HST service for every seat the airline takes off the aircraft³³⁹, then the impact from the HST journey should not be attributed only to the airline HST service but also to the TOC HST service, thus not all of the impact should be attributed to airline and railway integration. While this might be a good practical approach, it means that for the aircraft journey impacts are measured in average units while for the HST they are measured in marginal units, and this is methodologically inconsistent. Consequently, average units were used for the airline's HST service as well.

With regard to the use of 'value transfer', the experience shows that this is a sound procedure with respect to estimates of environmental impact, mainly because the scientific uncertainty associated with such estimates would remain if the values were specifically estimated for this research. Furthermore, evaluating such estimates, e.g. NOx emission contribution to LAP, lies outside the expertise of the transport planner making the use of value transfer almost the only option. Perhaps, a more robust approach is to rely on several studies and to extract from them a value that should be transferred to other studies, either through statistical analysis of several studies³⁴⁰ or an average of findings in different studies. The latter approach was used to reach the cost estimates of LAP and climate change used in this research, and as long as the results represent the same impact³⁴¹ this is considered a good and practical approach. For the FA, there is no problem with using 'value transfer' and often, due to commercial confidentiality, this is the only option available.

For the value of time analysis, the use of 'value transfer' was more problematic since the specific circumstances in which the values were originally estimated have more influence on the results and are likely to be very different from one study to another. Nevertheless, an evaluation of specific values for this research would not solve the methodological obstacles incurred and would not necessarily have led to better results.

³³⁸ In practice, some of the estimates used were in passenger units so an assumption on the LF was necessary to convert them to seat units.

³³⁹ Which is the case assumed and one of the advantages of airline and railway integration.

³⁴⁰ This approach is termed meta-analysis, but it does not always produce very useful results and is still dependent on the subjective selection of studies to be analysed (see for example Button, 2003).

³⁴¹ For example, NOx emission impacts on climate change and not climate change impact in one study and LAP impact in another.

The reliance on 'value transfer' meant that in addition to 'operational' data 'scientific' data was necessary as well, but this did not limit the analysis in any way. Actually, it was lack of 'operational' data on delays and noise impact from HST which limited the analysis. The limitations in the 'scientific' data were related to the general level of scientific knowledge in the matter evaluated rather than to limitations in obtaining sufficient and appropriate data. It seems better data would have improved the analysis but would probably not have changed the conclusions.

One methodological aspect which has so far not been addressed relates to the international nature of the beneficiaries from airline and railway integration. While the costs of connecting Heathrow with the CTRL are borne by the UK, the benefits are not solely local. Travel time savings would be enjoyed by an international mix of passengers, and the environmental benefits are assumed to be divided between the UK and France (LAP and noise) and the rest of the world (climate change)³⁴². The suggestions in the literature are contradicting. The inspector in the T5 inquiry concludes: "I do not believe that it is either realistic or desirable to exclude the benefits to foreign travellers" (Vandermeer, 2001: 9.3.32), on the other hand, "the Treasury's 'Green Book' on investment appraisal explicitly states that benefits should be restricted to UK residents only" (Environmental Audit Committee, 2003: 15), and the CfIT (2004) suggests adopting the French approach in which (value of time) benefits to foreign passengers are evaluated separately. However, within this research there was no need to resolve this issue since the aim was to identify and measure the benefits from airline and railway integration regardless of who enjoys them. One of the implications of the international nature of the benefits, especially benefits to EU members, is that the EU is more likely to contribute to the costs required to achieve them.

The methodology adopted to evaluate the operation of airline and railway integration was in part a compromise rather than a choice. However, one of the advantages of the methodology adopted is that it is generic in nature and can be easily used on other routes. With information on some basic characteristics of other routes (e.g. route distance and flight time), some conclusions can be drawn without step by step repetition of the analysis performed in this research.

With regard to the specific parts of the evaluation, methodological conclusions were made in each relevant section. Here, some comments are added and highlighted.

³⁴² OC benefits are likely to be enjoyed by a British airline since Heathrow is the base for airline and railway integration.

The FA imposed no methodological problems but its nature suggested data problems were more likely. Once these were overcome it became the most robust part of the evaluation, certainly within the CBA. The importance of using route and not km units in the case of aircraft and HST comparisons, evident in the analysis, was a very important contribution. Adopting the norm of using effect per km unit would have led to misleading conclusions.

The theory of assigning a monetary value to the travel time saved is clear, thoroughly researched, and has been empirically applied in many studies, yet it still proved to be a major challenge in this research. Also, the evaluation of travel time savings in minutes, which is considered a straightforward exercise, is not that simple and requires assumptions when data is not available or when variations in the data exist (e.g. flight time between London and Paris), which adds subjectivity. One thing the travel time analysis emphasised was the importance of HST average speed and not the maximum speed, the latter is very much influenced by the number of stops the HST makes when the line is an entirely HST line.

The methodological difficulties in evaluating the VTTS were discussed already. The main weakness of current practices and available estimates is that the VTTS does not account for the possibility to engage in other activities while travelling. This is believed to significantly affect the VTTS although no empirical evidence for this was found. The analysis made it clear that there is a high penalty for having to break the journey and transfer between services. However, it is not clear to what extent the transfer values in the literature represent the true penalty assigned by passengers. The above suggests that a reassessment of the use of the 'value of time' in evaluation is needed, especially to account for the way travel time is used, and consequently the changes in the notion of the value of travel time.

In light of the dependency of the travel time savings on the assumptions made, it seems that travel time reliability would play an important part in the choice passengers make between modes and this should be added to the evaluation.

The promotion of public transport also results in emphasis on better use of different modes within one journey, or integration between modes. From an evaluation perspective, this marks a change from comparing modes, e.g. train vs. plane, towards comparing alternative journeys, each consists of more than one mode, and how the different modes can be used together to get from A to B. This approach was taken in the research and seemed to pose a methodological challenge, mainly (and almost only) with respect to VTTS analysis. The main challenge seems to be an accurate estimate of the transfer penalty. In this case travel time savings in minutes would not say much.

From the outset, the evaluation of environmental impact posed the main challenge due to the nature of environmental impacts in general (and the scientific uncertainty associated with them) and the impact of aircraft operation in particular. The results and the quality of the conclusions were hardly affected by the quality and availability of data, an exception was the evaluation of the reduction in noise pollution. The breaking of the evaluation into the different stages of the 'path to reach monetary evaluation of environmental impact' proved very useful and should be adopted as a framework which allows a better understanding of the meaning of the results based on the stage in the 'path' they relate to.

6.2.2 The use of evaluation practices by decision makers

Evaluation practices provide critical and valuable information for decision makers, whichever method is used. However, the way this information is used to support, and even to justify, decisions is sometimes problematic. The increasing weight given to the results of the evaluation in making a decision leads to two things. First, the evaluation process is influenced by the desired outcome from the evaluation, and second, the limitations, inherent in any evaluation process, are concealed or ignored. It is hard to prove such claims, and especially the extent to which the results of evaluations are biased towards a desired outcome rather than just uncertain. Flyvbjerg et al (2003) provide evidence for this, and the use of optimism bias³⁴³ is another evidence.

The 'misuse' of the evaluation results is sometimes the reason for changing and amending evaluation practices. The move from CBA to MCA might also be associated, to some degree, with the relative ease in which manipulation of the results can be hidden within a benefit cost ratio or NPV estimates. However, in France a change in the opposite way took place. "In France recently, a move away from multi-criteria analysis (in extensive use since the late eighties) has occurred, due to lack of procedures for aggregating the evaluations of the individual criteria and unregulated weights that were left to the whim of the decision-takers...[this has result] in disillusionment with the multi-criteria evaluation process and the return to a 'monetising' approach" (Sayers et al, 2003: 96). In this research, adding different categories of benefits within a MCA was preferred over giving weight to the different categories, leading to prefer the CBA over the MCA as the main evaluation tool. However, acknowledging the limitations in the CBA and recognising the benefits from using MCA (without the aggregation of different categories) led to the use of both methods.

³⁴³ "Many project parameters are effected by optimism - appraisers tend to overstate benefits, and understate timings and costs...To redress this tendency, appraisers should make explicit adjustments for this bias" (HM Treasury, 2003: 29).

The main problem in the decision making process is the transparency of the evaluation and the extent to which the end users of the evaluation are exposed to its limitations. This problem increases when the end users, e.g. decision makers, are not involved in the evaluation process and thus have no clear idea of the assumptions used, the sensitivity of the results to them, and/or the limitations in general of the evaluation³⁴⁴. In other words, they have no 'feel' for the results. Using CBA and MCA together, in a way that each impact is measure in several ways and units, partly overcomes the problem since it does not show one number (such as the NPV) to base the decision on, and it is more likely to reveal when the results are sensitive to assumptions or the methodology used. In addition, performing the evaluation 'closer' to decision makers would help them to make better use of the results.

However, there is no way to separate subjectivity from the way evaluation results are interpreted, and this must be recognised. This recognition should lead to the reversal of the process in which the evaluation is used as a decision making tool rather than a decision support tool. Thus, rigorous evaluation should be performed for any project or policy change, but its results should not be the sole justification for accepting or rejecting a project. Similarly, the effort to measure and quantify external and wider economic effects, especially in monetary units, should continue and be encouraged, but at the decision level there must be acceptance that it would probably not be possible to accurately measure everything in money. Therefore, it should be legitimate to accept projects even if the CBA shows they should not as long as there are strong arguments for doing so (see below). This, it seems, is currently almost unimaginable in the UK. Instead, in order to promote a specific policy which currently does not look favourable according to the evaluation results, evaluation practices need to be changed.

A good example is provided by the CfIT (2004) study on HST. The CfIT supports the construction of HST line in the UK and argue that the case for it is now stronger than it was in the past. Together with this general conclusion, the CfIT proposes a range of amendments to the evaluation procedures which it thinks are required, and that if accepted would make the case for HST in the UK, from a CBA perspective. These recommendations include changes to risk/optimism bias allowances and changes to the VTTS estimates used for HST. While these changes might be justified³⁴⁵, they should not be changed in order to make the case for HST. The CfIT has enough authority to just put forward the case for HST, and not

³⁴⁴ This seems to hold in most cases outside the academic world, since such work will usually be outsourced to consulting firms.

³⁴⁵ Changes to the VTTS estimate to account for the better 'working' conditions on board the HST were also recommended in this research.

the case for changing the evaluation procedures for it to show the case for HST in the UK. Furthermore, the CfIT study states that:

Given the scale of high-speed rail projects, the ultimate decision to proceed is a political one. It was clear in all countries that there was a clear distinction between the appraisal process and outcome and the ultimate political decision: uniquely of the countries studied, Japan has historically rejected the idea of carrying out formal economic appraisal because it cannot substitute for this political decision

(CfIT, 2004: 2.30, emphasis in original text)

The fact that the CfIT makes this statement but argues in support of HST through changes to the evaluation procedures is evidence of the (over) importance placed on the evaluation results as the basis for any policy or decision. Following the evaluation in this research, it is recommended that the evaluation practices be changed only when this applies across all future projects to be evaluated but not for a specific mode³⁴⁶.

Although relatively scarce in the literature, there are examples where decisions which were at odds with the evaluation results were taken and proved successful. The expansion of Singapore's airport and rail network is one such example (Phang, 2003). In this case, Singapore's competitive position was the main justification for the decisions made and this could not be included in the CBA.

The above suggests that the use of 'optimism bias', for example, is counter productive and can, as suggested by the CfIT (2004), lead to delaying plans for HST in the UK. Similarly, it would unnecessarily reduce the case for airline and railway integration by reducing the benefits, although their measurement was based on robust analysis. If 'optimism bias' is used it should apply to the MCA as well, and in this case it will affect different categories differently depending on the units and scale used.

The Green Book states that "before any possible action by government is contemplated, it is important to identify a clear need which it is in the national interest for government to address. Accordingly, a statement of the rationale for intervention should be developed" (HM Treasury, 2003: 11). The Green Book further requires the rationale for intervention to be clear and that it would be reasonable to assume that intervention would be cost-effective (ibid). This official approach is accepted as a model for decision making, and it is argued

³⁴⁶ This applies to parameters such as optimism bias but not to VTTS, which are often mode specific.

that this research follows the requirement to justify airline and railway integration to this extent.

6.3 Conclusions and further research

Rethinking the future of demand requires us to rethink the future of supply also, and that has not yet been done

(Goodwin, 2003: 42, my emphasis).

The above quote was made with reference to rail and road transport but it equally holds for rail and air transport. With regard to the problems faced by the ATI, and its future operation, 'rethinking the future of demand' for air travel means that future supply should include the railways. Any discussion on future supply of 'air' services should not be confined to new runways but must consider the potential of the railways to substitute and complement aircraft services as well. For this to take place, (international) air transport should not be considered separately from (domestic) land transport in terms of policy and infrastructure planning, since they are all part of the same transport network. 'Integration' as a policy target should aim to integrate air and surface modes and not only surface modes. When this is implemented a HST/rail station becomes a natural option in any airport development.

Overall, two main recommendations follow from the research. The first recommendation is to include the railways, and especially HSTs, in any discussion on the future of air transport. Following from this, the definition of air transport infrastructure should include HST lines and stations. The second recommendation is for airline and railway integration to be considered and not just rail services at airports. Therefore, airline and railway integration should be adopted as the model to promote aircraft and HST substitution.

When considering airline and railway integration it is crucial that the following principles are followed in order to secure the benefits from airline and railway integration. These principles are the recommendations for the implementation of mode substitution through integration.

1. Aircraft and HST substitution should not lead, in general, to competition between the railways and the ATI/airlines, since such competition discourages the ATI from advocating mode substitution³⁴⁷. This means that the HST service that substitutes the aircraft service must begin at the airport;
2. It is not enough to prevent competition, on a specific route, between the modes and to begin the rail service at the airport. Full integration between the HST service and the

³⁴⁷ It is acknowledged that competition, in itself, is beneficial to passengers but the benefits from airline and railway integration are believed to outweigh the loss of benefits due to reduced competition. Furthermore, the effect of airline and railway integration on the level of competition is not clear (see section 5.2.4.1).

remaining aircraft services should be strived for. Such integration refers mainly to the integration of the air and rail services from the passenger point of view (e.g. integration of the reservations, ticketing, customer service, time-tables, etc.);

3. The integration of the services requires the rail station to be an integral part of the (air) terminal to allow fast and seamless transfer of passengers and their luggage between the modes. The rail station should not be located somewhere within the vicinity of the airport, but it must be as close as possible to the aircraft;

4. For successful airline and railway integration the airport's HST/rail station must be a through station on a main line³⁴⁸ to ensure high level of service in terms of destinations and frequency of service. Following the first three principles but connecting the airport to the rail network through, for example, a branch line, would significantly limit the potential benefits.

The above principles embody the concept of airline and railway integration which the research promotes and recommends as the model for mode substitution. This model is considered a win-win option for the different stakeholder groups associated with the ATI, namely the operators, passengers, and society, although it was not found to be the panacea solution to the problems faced by the ATI and to meeting the forecast growth in demand for air services.

The evaluation of airline and railway integration showed that the airlines and airports could benefit from increased passenger capacity at a much lower environmental cost, thus meeting current and/or future demand in a more acceptable way, and they will also benefit from improved network economics (more destinations and frequency of service), increased catchment area, and better access (by public transport) to their services. However, the actual benefits depend on the extent to which the demand for the new HST/rail capacity at Heathrow equals the demand for the planned runway capacity, since the two will not serve the exact same markets. This has not been analyzed. Another shortcoming of the analysis is that, due to lack of data, the share of the transfer traffic market (the basis for integration) in the overall traffic on the case study route was not considered³⁴⁹. If this market is not significant on services between Heathrow and CDG, hence the origin-destination market dominates, then it is crucial to investigate why passengers prefer the plane over the train.

The railways are also expected to benefit from integration, mainly from increased demand on profitable markets. Passengers will benefit mainly from shorter travel times on some routes; better travelling conditions, which might even compensate for longer journey time on some

³⁴⁸ This relates to major airports. For smaller airports such a station might not be appropriate.

³⁴⁹ The data available only indicated that this is, overall, an important market at Heathrow.

routes; and better access to airports by public transport. Society would benefit from reduction in the environmental pollution imposed by the ATI, but these benefits depend on the extent to which integration is used as a mean to meet current demand rather than new demand for air services.

Current air transport policy in the UK is set out in the Aviation White Paper (DfT, 2003b), and it is mainly based on recommendations to construct new runways in the South East, including Heathrow. The White Paper did not consider airline and railway integration, and therefore this research alerts policy makers to the benefits from integration at Heathrow before the recommendations are implemented. This makes the research extremely timely.

The UK air transport policy has three main goals for Heathrow as the national air gateway and hub airport, namely to preserve its international competitive position as a transfer/hub airport, in order to secure its contribution to the national economy; to increase accessibility to it from the regions, and thus accessibility from the regions to London and the rest of the world; and to curb its impact on the environment. These goals cannot be reconciled through additional runways but only through, as this research has demonstrated, connecting Heathrow to the rail network and the future HST line/network, and through airline and railway integration that follow the four principles. This may also be applicable in the case of other countries and their hub airports. Another policy goal airline and railway integration at Heathrow would fulfil is integration between the transport modes, one of the main pillars of both UK and EU transport policy.

In practice, this means that plans to connect Heathrow with the CTRL and to provide a conventional and HST station at Heathrow, which will be located in between the five (air) terminals and would be a major station on a railway main line, should replace plans for a third runway and a sixth terminal at Heathrow. The research has shown that the benefits from the rail alternative include the same benefits from the runway alternative, plus additional benefits, and at a comparable cost. Furthermore, for Heathrow to 'catch up' with its main competitors, it must invest in its land side and offer its customers high quality rail accessibility and service, and an option for airlines to peruse air-rail integration. An obstacle to implementing the above, however, is its funding. The ATI is expected to fund the third runway at Heathrow and therefore, if the HST station substitutes the runway, also the rail infrastructure. However, with lack of interest in integration from the ATI (see below) it will not consider investing in it (or even supporting it). At the same time, the Government, which aim for the private sector to participate in the finance of (HST) rail infrastructure, would not agree to participate in funding the infrastructure for a privatised, often profitable, industry.

From the rail industry perspective, the decision on whether to build a South-North HST should not be based on the potential for airline and railway integration. Therefore, if a decision to construct the HST line is taken this line must include Heathrow as a main station. From a general perspective, the demand for rail services generated by Heathrow and the benefits from airline and railway integration are believed to justify this. Alternatively, if a decision is taken not to proceed with the construction of a HST line, actions should then be taken to connect Heathrow with the current main line(s) by diverting their alignment. Alternative rail connections to Heathrow, e.g. a spur from the main line(s), would not provide comparable benefits and may not be worthwhile.

In light of the evidence this research provides, the question remains why airline and railway integration is currently not considered, and not advocated by the ATI. And consequently, what changes might bring about a reassessment?

The answer to the first question is that, in the UK at least, it is currently not an option due to lack of infrastructure. With the lack of plans and even interest from the government, and with the railways and the ATI industries being 'blind' to the potential in closer cooperation, it is clear that integration will not be an option for many years. However, the evidence from Frankfurt, CDG, and Schiphol airports all show that when the infrastructure for integration is provided some form of airline and railway integration does take place.

In addition, there seems to be cultural differences between the industries, manifested in the different operating practices, which act as a barrier to closer cooperation. These differences, the result of different (de)regulation/privatisation history, mean that the ATI does not see the railways as a competent partner for cooperation. Furthermore, the airline industry is still undergoing structural changes and faces financial crisis which do not leave room for consideration of major changes that include mode substitution on a large scale. Finally, and very significant, the ATI can still operate under a 'business as usual' strategy (evident in the fact that over 60 daily flights are operated between London and Paris). Yet, it is important to note that integration is still a relatively new concept, and as supply of infrastructure for integration increases, more experience in integration is gained, and as the problems faced by the ATI intensify, it is expected to become much more common practice. Already the study by IATA (2003) suggests a change in attitude in the ATI towards integration.

For the UK, the trigger for change that will put airline and railway integration on the agenda might be the beginning of HST services directly from London to CDG by Eurostar and under a code share agreement with AF. Such services would effectively make the new AF-KLM airline the new hub carrier for the UK. The KLM part of the company will serve the regions

through Schiphol, and the AF part of the company will serve parts of the South East through (HST services to) CDG. At the same time, Heathrow and BA will find themselves struggling to maintain their position in the transfer traffic market due to lack of runway capacity at Heathrow. For a government which aims to maintain Heathrow's position as an international hub, and sees it as a priority, this might be enough to start a debate on integration.

In more general terms, it is predicted that within a time period of 30-40 years major global airlines around the world, an evolution of today's major alliances, will operate a network of air and rail services. By then, passengers will be used to transferring between aircraft and rail services (some of which will be HST services) and to begin or end their air journey at the (city-centre) railway station. Within the above time period the first long-distance MAGLEV line will be opened in Japan connecting Tokyo and Osaka, as well as Tokyo's Narita and Haneda airports and Osaka's Kansai airport, by a 500 kph service (Chuo Shinkansen Ensen Gakusha Kaigi, 2001). The high speed achieved by MAGLEV trains substantially increases the potential for mode substitution and for airline and railway integration³⁵⁰, and this seems to be realized in Japan where currently no airline and railway integration takes place.

The research also provides policy makers with some methodological recommendations. Following the research, the use of a detailed empirical analysis, which includes the use of evaluation practices, is recommended as the basis for forming transport policies and for use as a tool to support decision making. However, the research highlighted the risk in making the evaluation results, especially if based only on CBA, the sole basis for a decision (i.e. a decision making tool). It is recognised that some elements of a transport policy or project cannot be evaluated by current practices and that, in addition, there is always a political dimension to any decision. The two official requirements to justify intervention, set by the UK government, namely a clear rationale and a cost effective intervention, should be sufficient to justify action if a detailed empirical evaluation has been carried out. This research has certainly fulfilled these requirements to justify a more detailed investigation in support of airline and railway integration at Heathrow.

With regard to best practice in evaluation methods, the analysis demonstrated that despite the limitations of CBA it is still unavoidably necessary to monetize different effects in order to compare benefits and costs and between categories of benefits. However, the research stresses that caution must be taken when doing so and recommends that the CBA results will be supported by other evidence including the results of a MCA.

³⁵⁰ Assuming an average speed of 500 kph, airline and railway integration on all the routes considered in section 4.4 (Table 49) would lead to travel time savings of at least 10 minutes compared to the aircraft journey (an exception is the route to Barcelona with only 4 minutes travel time savings).

The analysis also pointed out that in some circumstances the units most commonly used (i.e. passenger-km) are not the most appropriate and that it is useful and important to present the results in different units. In this research, the use of km units was inappropriate since it concealed an important characteristic of the modes compared, namely the distance each has to cover between origin and destination. Similarly, the results and conclusions were different depending on if passenger or seat units were used. This research has focused on the supply of services and therefore the seat units were considered more appropriate, but presenting the results also in passenger units has provided valuable information.

With respect to the practice of evaluating the value of travel time savings, policy makers must note that there are still limitations in applying the established theory to empirical analysis especially when two modes are compared and where two modes (or more) are used within the same journey. In addition, the analysis highlighted the importance in accounting for travel conditions in the evaluation of the value of travel time savings. Similarly, the research showed that environmental impact from transport operations can be quantified, also in monetary units, but that the results are mainly indicative rather than accurate.

The methodological framework developed in the research can be used to evaluate airline and railway integration on other routes and at other airports. The results obtained in this research already serve as an indication for the expected benefits on other routes and at other airports.

This research introduced the concept of integration and was the first to thoroughly examine it. Nevertheless, further research is required on aspects that were not fully covered by the research and this includes the following. Evaluating in a quantitative manner the indirect benefits of integration³⁵¹ and evaluating in more detail (separately) the benefits to airports and to the railways from integration. More specifically, and when suitable data is obtained, evaluation of the benefits from reduced noise pollution and reduced delays to services, following integration, should be carried out to complement this research.

In a broader perspective, the research emphasised the importance in carrying out more research to determine the contribution of the ATI to the (national) economy. Specifically, in the context of this research, it is crucial to evaluate the contribution to the (national) economy from serving the transfer traffic market at the national hub airport, especially in circumstances where the hub airport is congested and cannot meet local demand. Finally, research should be carried out on the scope for airline and railway integration in the freight market in order to give a more comprehensive picture of the total market.

³⁵¹ The benefits described in section 5.

Bibliography

- AACI (1992), "Airports – partners in vital economies", Airports Association Council International, European Region, Brussels, November in: Caves E. R., Gosling D. G. (1999), "Strategic airport planning", Pergamon, Amsterdam.
- Abelson P.W., Hensher D. A. (2001), "Induced travel and user benefits: clarifying definitions and measurement for urban road infrastructure", in: Button K. J., Hensher D. A., "Handbook of transport systems and traffic control", Pergamon, London.
- Aberle G. (1993), "High speed train development in Germany", in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.
- ACI, Airport Council International (2000), "ACI traffic data", ACI [www.airport.org (21/10/2000)].
- ACI, Airport Council International (2003) [www.airport.org/traffic/history/move2001.htm (16/07/2003)].
- ACI, Airport Council International (2004), "ACI passenger traffic reports", ACI [<http://www.airports.org> (28/04/2004)].
- AEF, Aviation Environment Federation (2000), "From planes to trains - realising the potential from shifting short-flights to rail", Friends of the Earth, October.
- AF, Air France (2003), "Schedules", AF [www.cgi.airfrance.fr (21/04/2003)].
- Airbus (2002a), "Global market forecast 2001 - 2020", Airbus, September [www.airbus.com/pdf/media/gmf2001.pdf (16/2/2003)].
- Airbus (2002b), "A380 briefing", Airbus.
- Airbus (2003), "Global market forecast 2003 - 2022", Airbus, December [www.airbus.com/pdf/media/gmf2003.pdf (20/06/2004)].
- Airbus (2004), "Orders and deliveries", Airbus [http://www.airbus.com/media/orders_n_deliveries.asp (30/06/2004)].
- Airline Business (2002), "Time is money", Airline Business, February, 68-69.
- Airline Business (2003), "BA grabs yet more Heathrow slots", Airline Business, November, 19.
- AirTrack Forum (undated), "Executive summary", AirTrack Forum, Surrey County Council.
- Air Transport Association (2003), "Airlines in crisis", Air Transport Association, March [www.airlines.org/public/industry/bin/airlinesincrisis.pdf (12/3/2003)].
- Air Transport World (2002a), "Facts & figures", Air Transport world, May, 81.
- Air Transport World (2002b), "Facts & figures", Air Transport world, June, 67.
- AirWise News (2003a), "Boeing shelves Sonic Cruiser", AirWise News, 16 February [<http://news.airwise.com/stories/2002/12/1040641517.html> (16/2/2003)].
- AirWise News (2003b), "New airports not needed says BA", AirWise News, 17 June [<http://news.airwise.com/stories/2003/06/1055851559.html> (17/06/2003)].
- AirWise News (2003c), "Beijing reveals new airport plan", AirWise News, 11 September [<http://news.airwise.com/stories/2003/06/1055851559.html> (14/09/2003)].
- AirWise News (2003d), "Airlines set to rebound - ICAO", AirWise News, 7 November [<http://news.airwise.com/stories/2003/08/1060690980.html> (06/11/2003)].
- AirWise News (2003e), "Ryanair profits 'in the bag'", AirWise News, 14 January [<http://news.airwise.com/display/story.html?name=2003/01/1042551105.html> (23/05/2004)].
- AirWise News (2004a), "US, EU close to open skies deal", AirWise News, 22 May [<http://news.airwise.com/stories/2004/05/1085138290.html> (22/05/2004)].
- AirWise News (2004b), "EU says no air deal with US before summit", AirWise News, 29 June [<http://news.airwise.com/stories/2004/06/1087993750.html> (29/06/2004)].
- AirWise News (2004c), "Airbus A380 puts on weight", AirWise News, 6 July [<http://news.airwise.com/stories/2004/07/1089017973.html> (06/07/2004)].

- AirWise News (2004d), "A380 changes to cost BAA USD\$385 million", AirWise News, 23 July [<http://news.airwise.com/stories/2004/07/1090317681.html> (23/07/2004)].
- Alder M. (2004), email exchange with the chairman of the British Air Line Pilot Association (BALPA) Flight Safety Group, March.
- Ampe F. (1995), "Technopole development in Euralille", in: Banister D. (Editor), "Transport and urban development", E&FN Spon, London
- Archer L. J. (1993), "Aircraft emissions and the environment: CO_x, SO_x, HO_x & NO_x", OIES papers on energy and the environment, Oxford Institute for Energy Studies, Oxford.
- Ashdown Environmental Ltd. (1994), "Assessment of operational airborne noise effects", prepared for Union Railways Ltd. to provide reference for the Channel Tunnel Rail Link Environmental Statement, Ashdown Environmental Ltd., Final Report, Volume 1.
- ATAG, Air Transport Action Group (1999), "Europe can't wait any longer", ATAG, Geneva, [www.atag.org/Europe/index.htm (13/10/2000)].
- ATAG, Air Transport Action Group (2000), "European Traffic Forecasts 1985-2015", ATAG, Geneva.
- Aujouannet D. (2002), email exchange with Airport de Paris (ADP), October.
- BA, British Airways (2003a), "Heathrow runway key to boosting Britain's economy", British Airways – Online Press Office – News Releases, May, 22 [www.britishairways.com (23/05/2003)].
- BA, British Airways, (2003b) web site [www.britishairways.com/travel/fx/public (21/04/2003)].
- BAA (2001), "conditions of use – including airport charges from 1 April 2001", BAA, March.
- BAA (2002), "Heathrow delivering for London and the regions: a surface access strategy for Heathrow – the next five years", BAA, Annual progress report, May.
- BAA (2003a), "London Heathrow flight information", BAA web site [www.innovatallc.com/LHR/htmaplhr.asp (21/04/2003)].
- BAA (2004), "Destinations to/from Heathrow", BAA web site [www.baa.com/main/airlinedb/heathrow/any_any_page.html (09/03/2004)]
- Baker C., Field D. (2001), "Jumping the tracks", *Airline Business*, June.
- Banister D., Hall P. (1993) "The second railway age", *Built Environment*, 19, 3/4, November, 157-162.
- Banister D., Berechman J. (2000), "Transport investment and economic development", UCL Press, London.
- Bates J., Polak J., Jones P., Cook A. (2001), "The valuation of reliability for personal travel", *Transportation Research Part E*, 37, 191-229.
- Beuthe M. (2002), "Transport evaluation methods: from cost-benefit analysis to multicriteria analysis and the decision framework", in: Liana G., Pearman A., Tandon A., Tsamboulas D., Reynaud C. (Editors), "Project and policy evaluation in transport", Ashgate, Aldershot.
- Black W. A. (2003), "Transportation – a geographical analysis", The Guilford Press, London.
- Boeing (2002), "Current market outlook", Boeing Commercial Airplanes, July, [www.boeing.com/commercial/cmo/cmo2002.pdf (16/2/2003)].
- Boeing (2003a), "Current market outlook", Boeing Commercial Airplanes, July, [www.boeing.com/commercial/cmo/pdf/CMO2003.pdf (06/11/2003)].
- Boeing (2003b), "Boeing 7E7 will provide new solutions for airlines, passengers", Boeing, [www.boeing.com/commercial/7e7/background.html (10/11/2003)].
- Boeing (2004), "Current market outlook 2004", Boeing Commercial Airplanes [www.boeing.com/commercial/cmo/pdf/CMO2004.pdf (20/06/2004)].
- Bonafous A. (1987), "The regional impact of the TGV", *Transportation*, 14, 127-137.
- Bouley, J. (1986), "Innovative areas: high speeds", in: ECMT, European Conference of Ministers of Transport, "European dimension and future prospects of the railways", ECMT, Paris.

- Brent R. J. (1996), "Applied cost-benefit analysis", Edward Elgar, Cheltenham.
- Bristow A. L., Nellthorp J. (2000), "Transport project appraisal in the European Union", *Transport Policy*, 7, 51-60.
- Bromhead P. (1973), "The great white elephant of Maplin Sands", Paul Elek, London.
- Brons M., Nijkamp P., Pels E., Rietveld P. (2003), "Railroad noise: economic valuation and policy", *Transportation Research Part D*, 8, 169-184.
- Bronzaft A. L. (2003), "United States aviation transportation policies ignore the hazards of airport-related noise", *World Transport Policy & Practice*, 9, 1, 37-40.
- Brown R. (2004), "High speed rail in the UK: achievements and prospects", ILT André Bénard lecture by Eurostar Chief Executive, Cavendish Conference Centre, London, 6 May.
- Bruinsma F., Rietveld P. (1993), "Urban agglomerations in European Infrastructure networks", *Urban Studies*, 30, 6, 919-934.
- Brussels Airport, 2003 [<http://www.brusselsairport.be> (25/08/2003)].
- Bråthen S., Eriksen K. S., Hjelle H. M., Killi M. (2000), "Economic appraisal in Norwegian aviation", *Journal of Air Transport Management*, 6, 153-166.
- Buchanan and Partners (1995), "Optimising rail/air intermodality in Europe", European Commission – DG VII, London, November.
- Button K. (Editor) (1991), "Airline deregulation international experiences", David Fulton Publishers, London.
- Button K. (1993), "Transport, the environment and economic policy", Edward Elgar, Aldershot.
- Button K. (2002), "Debunking some common myths about airport hubs", *Journal of Air Transport Management*, 8, 177-188.
- Button K. (2003), "The potential of meta-analysis and value transfers as part of airport environmental appraisal", *Journal of Air Transport Management*, 9, 167-176.
- Button K. (2004), "Airlines", paper presented at the STELLA/STAR Focus Group 5 meeting, Athens, Greece, 4-5 June.
- Button K., Haynes K., Stough R. (1998), "Flying into the Future - Air Transport Policy in the European Union", Edward Elgar, Northampton.
- Button K., Stough R. (2000), "Air transport networks – theory and policy implications", Edward Elgar, Cheltenham.
- CAA, Civil Aviation Authority (2004), "UK Airport statistics: 2003 – annual", CAA, Economic Regulation Group [www.caa.co.uk/erg/erg_stats/sgl.asp?sglid=3&fld=2003Annual (18/05/2004)].
- Capafons J. I., Sosa C. D., Vina C. M. (1999), "A reattributorial training program as a therapeutic strategy for fear of flying", *Journal of Behavior Therapy and Experimental Psychiatry*, 30, 259-272.
- Caves E. R., Gosling D. G. (1999), "Strategic airport planning", Pergamon, Amsterdam.
- CEC, Commission of the European Communities (1996), "White Paper – a strategy to revitalise the community's railways", Commission of the European Communities, COM(96)421final, July.
- CEC, Commission of the European Communities (1999), "Air transport and the environment towards meeting the challenges of sustainable development", Commission of the European Communities, COM(1999) yyy final, Brussels, November [http://europa.eu.int/comm/transport/themes/air/englishe/library/environment_com_%20en.pdf (8/12/2002)].
- CEC, Commission of the European Communities (2001), "European transport policy for 2010: time to decide", Commission of the European Communities, COM(2001)370, Brussels, September [http://europa.eu.int/comm/off/white/index_en.htm (15/2/2002)].
- Central Japan Railway Company (2001), "Annual report 2000", Central Japan Railway Company.
- Central Japan Railway Company (2003), "Central Japan Railway Company data book 2002", Central Japan Railway Company.

- CfIT, Commission for Integrated Transport (2001a), "A comparative study of the environmental effects of rail and short-haul air travel", prepared by Watkiss P., Jones R., Rhodes D., Hardy A., Handley C., Walker C., September.
- CfIT, Commission for Integrated Transport (2001b), "European best practice in the delivery of integrated transport, report on stage 1: benchmarking", CfIT, November.
- CfIT, Commission for Integrated Transport (2003), "A report on aviation's external costs", CfIT, September, [www.cfit.gov.uk/reports/aec/index.htm (01/09/2003)].
- CfIT, Commission for Integrated Transport (2004), "High speed rail: international comparisons", prepared by Steer Davis Gleave for CfIT, February.
- Chaaban F. B., Mezher T., Ouwajan M. (2004), "Options for emissions reduction from power plants: an economic evaluation", *Electrical Power and Energy Systems*, 26, 57-63.
- Cheng-Lung W., Caves R. E. (2000), "Aircraft operational costs and turnaround efficiency at airports", *Journal of air transport Management*, 6, 201-208.
- Chuo Shinkansen Ensen Gakusha Kaigi (2001), "Linia Chuo Shinkansen de Nihon ha Kawaru (the future change in Japan by linear Chuo shinkansen)", PHP, Tokyo.
- CODA, Central Office for Delay Analysis (1999), "Delays to Air Transport in Europe Annual Report 1998", Eurocontrol/ECAC.
- CODA, Central Office for Delay Analysis (2000), "Delays to Air Transport in Europe Annual Report 1999", Eurocontrol/ECAC.
- CODA, Central Office for Delay Analysis (2001), "Delays to Air Transport in Europe Annual 2000", Eurocontrol/ECAC.
- CODA, Central Office for Delay Analysis (2002), "Delays to Air Transport in Europe Annual 2001", Eurocontrol/ECAC.
- CODA, Central Office for Delay Analysis (2003), "Delays to Air Transport in Europe Annual Report 2002", Eurocontrol/ECAC.
- CODA, Central Office for Delay Analysis (2004), "Delays to Air Transport in Europe Annual Report 2003", Eurocontrol/ECAC.
- Colville R. N., Hutchinson E. J., Mindell J. S., Warren R. F. (2001), "The transport sector as a source of air pollution", *Atmospheric Environment*, 35, 1537-1565.
- Crossrail [<http://www.crossrail.co.uk> (04/09/2003)].
- CTRL, Channel Tunnel Rail Link (undated), "Perceptible vibration and groundborne noise from the operation of the CTRL", Information paper C10, CTRL.
- CTRL, Channel Tunnel Rail Link (2004), CTRL web site [<http://www.ctrl.co.uk/building> (23/04/2004)].
- Daniels R., Adamowicz V. (2000), "Environmental valuation", in: Hensher D. A., Button K. J. (Editors), "Handbook on transport modelling", Elsevier Science Ltd., Oxford.
- Davis S. C., Diegel S. W. (2002), "Transportation energy data book: edition 22", Centre for Transportation Analysis Engineering Science & Technology Division, Oak Ridge National Laboratory, Tennessee, September.
- DEFRA, Department for Environment, Food & Rural Affairs (2001), "Towards a national ambient noise strategy - A consultation paper from the air and environmental quality division", DEFRA, November [www.defra.gov.uk/environment/consult/noiseambient/pdf/ambientnoise.pdf, (14/1/2002)].
- DEFRA, Department for Environment Food & Rural Affairs, HM Treasury (2002), "Estimating the social cost of Carbon emissions", Government Economic Service Working Paper 140, London, January.
- Dennis N. (2001), "Developments of hubbing at European airports", *Air & Space Europe*, 3, ½, 51-55.
- Department of Transport (1996), "Calculation of railway noise 1995 (supplement 1)", The Department of Transport.
- DETR, Department of the Environment, Transport and the Regions (1998), "A new deal for transport: better for everyone - The Government's White Paper on the Future of Transport", DETR, July.

- DETR, Department of the Environment, Transport and the Regions, (2000a) "The future of aviation - the government's consultation document on air transport policy", DETR, London, December.
- DETR, Department of the Environment, Transport and the Regions (2000b), "Valuing the external costs of aviation", DETR, 12 December [www.detr.gov.uk/atwp/exvalue/index.htm (22/3/2001)].
- DETR, Department of the Environment, Transport and the Regions (2000c), "Air traffic forecasts for the United Kingdom 2000", DETR, June [www.aviation.dtlr.gov.uk/atfuk2000/index.htm (16/5/2002)].
- DETR, Department of the Environment, Transport and the Regions (2000e), "Guidance on the Methodology for Multi-Modal Studies", DETR, May [www.detr.gov.uk/itwp/mms/vol1/index.htm (22/03/2002)].
- DfT, Department for Transport (2003a), "The future development of air transport in the United Kingdom: South East", Second Edition, Department for Transport, February.
- DfT, Department for Transport (2003b), "The future of air transport", White Paper, Department for Transport, December.
- DfT, Department for Transport, and HM Treasury (2003), "Aviation and the environment using economic instruments", Department for Transport and HM Treasury, March, London.
- Dings J. M. W., Wit R. C. N., Leurs B. A., Bruyn S. M. de, Davidson M. D., Fransen W. (2002a), "External costs of aviation", CE Delft, Delft, February.
- Dings J. M. W., Wit R. C. N., Leurs B. A., Bruyn S. M. de, Davidson M. D., Fransen W. (2002b), "External costs of aviation – background report", CE Delft, Delft, February.
- Dodgson J., Spackman M., Pearman A. D., Philips L. D. (2000), "Multi-criteria Analysis: a manual", DETR, London.
- Doganis R. (1991), "Flying off course – the economics of international airlines", 2nd Edition, Routledge, London.
- Doganis R. (1992), "The Airport Business", Routledge, London.
- Doganis R. (2001), "The airline business in the 21st century", Routledge, London.
- Doganis R. (2002a), "Flying off course", 3rd Edition, Routledge, London.
- Doganis R. (2002b), "The future of hubbing in London", Rigas Doganis & Associates, October [www.baa.co.uk/pdf/HubbinginLondon.pdf (23/5/03)].
- Doganis R., Dennis N. P. S. (1989), "Lessons in hubbing", *Airline Business*, March, 42-45, in: Button K., Stough R. (2000), "Air transport networks – theory and policy implications", Edward Elgar, Cheltenham.
- DoT, Department of Transport (1995), "Calculation of railway noise 1995", The Department of Transport.
- DTI, Department for Trade and Industry (2003), "Energy White Paper: our energy future – creating a low carbon economy", The Stationary Office, London, February.
- DTLR, Department of Transport, Local government, and the Regions (2001), "Terminal Five decision letter", DTLR, November [www.planning.dtlr.gov.uk/callins/terminal5/decision.htm (12/01/2002)].
- DTLR, Department of Transport, Local government, and the Regions (2002), "South East and East of England regional air services study – stage two: appraisal findings report-supporting documentation – capital costs", DTLR, January.
- EC, European Commission (1996), "Interaction between high speed and air passenger transport - interim report", Interim report on the Action COST 318, European Commission, April.
- EC, European Commission (1998), "Interaction between high speed and air passenger transport", Final report on the Action COST 318, European Commission, Luxembourg.
- EC, European Commission (2001), "Trans-European transport networks" The European Commission [www.europe.eu.int/comm/transport/themes/network/english/tentpp9807/tentpp9807.html (18/2/2001)].

- ECAC/EU, European Civil Aviation Conference/European Union (1999), "Airport Capacity – Challenges for the Future", Proceedings from the ECAC/EU dialogue with the European air transport industry, Salzburg, 15-16 April.
- Endres G. (2001), "The illustrated directory of modern commercial aircraft", Salamander Books Limited, London.
- Environmental Audit Committee (2003), "Budget 2003 and aviation", House of Commons, The Stationery Office Limited, London, July.
- EPA, Environmental Protection Agency (1999a), "Indicators of the environmental impacts of transportation", Second edition, EPA, EPA 230-R-99-001, October.
- EPA, Environment Protection Agency (1999b), "Evaluation of air pollutant emissions from subsonic commercial jet aircraft", EPA, EPA 420-R-99-013, April.
- ERA, European Regions Airlines Association, (2000), [www.eraa.org (12/11/2001)].
- EUNET (1998), "Deliverable D9: Measurement and valuation of the impacts of transport initiatives", EUNET, Volume 1: Main Text, Work Package 4, December.
- Eurocontrol (undated), "Customer guide to charges", Central Route Charges Office, Eurocontrol [www.eurocontrol.be/dgs/activities/crco/download/files/customer guide.pdf (10/16/2002)].
- European Communities (2002), "Trans-European transport network TEN-T priority projects", European Communities, Luxemburg.
- European Communities (2003), "Trans-European networks: introduction", European Communities [http://europa.eu.int/scadplus/leg/en/lvb/l06019.htm (07/08/2003)].
- Eurostar (2003a), "Eurostar a seamless journey to the continent", Eurostar [www.eurostar.co.uk/dctm/jsp/about/press.jsp (21/7/2003)].
- Eurostar (2003b), "Timetables", Eurostar [www.eurostar.co.uk (21/04/2003)].
- Eurostar (2004a), "Latest results signal new era for Eurostar", Eurostar website, 12, January [www.eurostar.com/dctm/jsp/subhome (04/03/2004)].
- Eurostar (2004b), "Eurostar timetables - 26 June to 4th September 2004", Eurostar [www.eurostar.com/dctm/html/timetables/timetables_270604_english.html (11/06/2004)].
- Eurostar (2004c), "Ownership & structure", Eurostar [www.eurostar.com/dctm/jsp/subhome/detail.jsp?page=CI&id=09001a5980115f2a (18/06/2004)].
- Eyre N. J., Ozdemiroglu E., Pearce D. W., Steele P. (1997), "Fuel and location effects on the damage costs of transport emissions", *Journal of Transport Economics and Policy*, **31**, 5-24, in: Lu C. H. Y., Morrell P. (2001), "Evaluation and implications of environmental charges on commercial flights", *Transport Reviews*, **21**,(3), 377-395.
- Evans A. (1999), "Value of travel time savings", Intercollegiate MSc course in Transport, Unit T4: Transport Economics, Lectures 14 and 15, University College London, November.
- Feldhoff T. (2003), "Japan's capital Tokyo and its airports: problems and prospects from subnational and supranational perspectives", *Journal of Air Transport Management*, **9**, 241-254.
- Finnair (2002), "Blue wing", Finnair, December.
- Flint P. (2002), "No peaking", *Air Transport World*, November, 22-27.
- Flyvbjerg B., Bruzelius N., Rothengatter W. (2003), "Megaprojects and risk", Cambridge University Press, Cambridge.
- Franke M. (2004), "Competition between network carriers and low-cost carriers – retreat battle or breakthrough to a new level efficiency?", *Journal of Air Transport Management*, **10**, 15-21.
- Furuichi M., Koppelman S. F. (1994), "An analysis of air travellers' departure airport and destination choice behaviour", *Transportation Research Part A*, **28**, 3, 187-195.
- Giorgi L., Tandon A. (2000), "The theory and practice of evaluation - conclusions from the first TRANS-TALK workshop", The Interdisciplinary Centre for Comparative Research in the Social Science, July, [www.iccr-international.org/trans-talk/index-reports.html (18/4/2002)].

- Giuntini A. (1993), "high speed trains in Italy" in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.
- Glaister S. (1999), "Observations on the new approach to the appraisal of roads projects", *Journal of Transport Economics and Policy*, **33**, 2, 227-234.
- Gómez-Mendoza A. (1993), "History and the AVE", in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.
- Graham A. (2000), "Demand for leisure air travel and limits to growth", *Journal of Air Transport Management*, **6**, 109-118.
- Graham A. (2001), "Managing airports - an international perspective", Butterworth Heinemann, Oxford.
- Graham B. (1997), "Regional airline services in the liberalized European Union single aviation market", *Journal of Transport Geography*, **3**, 4, 227-238.
- Graham B., Guyer C. (1999), "Environmental sustainability, airport capacity, and European air transport liberalization: irreconcilable goals?", *Journal of Transport Geography*, **7**, 165-180.
- Graham B., Guyer C. (2000), "The role of regional airports and air services in the United Kingdom", *Journal of Transport Geography*, **8**, 249-262.
- Grant-Muller S. M., Mackie P., Nellthorp J. and Pearman A. (2001), "Economic appraisal of European transport projects: the state-of-the-art revisited", *Transport Reviews*, **21**, 2, 237-261.
- Goodwin, P. (2003), "What future for the rail in the ten year plan for transport?", University College London, Report to the All Party Parliamentary Rail Group, November.
- Grayling T. (2001), "Air transport growth: the macroeconomic viewpoint", paper presented at the Royal Geographical Society conference: Policy directions in UK air transport: the next ten years, 14 March 2001, London.
- Grayling T., Bishop S. (2001), "Sustainable aviation 2030", Institute for Public Policy Research, August.
- Gunn H. (2003), "The assumption underpinning how travel time savings are valued merit careful scrutiny", *Local Transport Today*, **367**, 29 May, 12.
- HACAN, Heathrow Association for the Control of Aircraft Noise (2002) [www.hacan.org.uk (22/04/2002)].
- Hall P. (1999), "High-speed train and air: competitive or complementary?", Presentation for Lake Arrowhead Transportation Symposium, 25 October.
- Hall P. (2001), "High-speed rail comes to London, Access, 19, Fall.
- Hensher A. D. (2001), "Measurement of the valuation of travel time savings", *Journal of Transport Economics and Policy*, **35**, 1, January, 71-98.
- HM Treasury (2003), "The Green Book – Appraisal and evaluation in Central Government", Treasury Guidance, HM Treasury, January, London.
- Holloway M., Watson R. (2001), "Achieving effective rail services to airports", paper presented at the 33rd UTSG conference, January, Oxford.
- House of Commons Transport Committee (2003), "Aviation", House of Commons Transport Committee, Sixth report of session 2002-03, Volume I, HC 454-I, The Stationery Office Limited, July.
- House of Commons Transport Committee, (2004) "The future of the railway", House of Commons Transport Committee, Seventh report of session 2003-04, Volume I, HC 145-I, The Stationery Office Limited, April.
- Humphreys I. (1999), "Privatisation and commercialisation changes in the UK airport ownership patterns", *Journal of Transport Geography*, **7**, 121-134.
- Humphreys I. (2003), "Organizational and growth trends in air transport", in: Upham P., Maughan J., Raper D., Thomas C. (Editors), "Towards sustainable aviation", Earthscan, London.
- IARO, International Air Rail organisation, Air Transport Action Group, Airports Council International (1998), "Air rail links – guide to best practice", International Air Rail organisation, Air Transport Action Group, Airports Council International, September.

- IATA, International Air Transport Association (2001), "World air transport statistics", 45th Edition, IATA.
- IATA, International Air Transport Association (2003), "Air/rail intermodality study", IATA, February.
- ICAO, International Civil Aviation Organization (1998), "Manual of airport and air navigation facility tariffs", ICAO.
- ICAO, International Civil Aviation Organisation (2002a), "Balanced approach to aircraft noise management", ICAO [www.icao.int/icao/en/env/noise.htm (23/4/2002)].
- ICAO, International Civil Aviation Organisation (2002b), "ICAO engine exhaust emissions data bank", ICAO, July [www.QinetiQ.com/aviation_emissions_databank/index.asp (30/06/2003)].
- Innovata (2003), "Innovata Flight Schedules", Innovata [www.quicktrip.com/flightbase/schedules (16/07/2003)].
- Innovata (2004), "Innovata Flight Schedules", Innovata [www.quicktrip.com/flightbase/schedules (12/03/2004)].
- IPCC, Intergovernmental Panel on Climate Change (1999), "Aviation and the global atmosphere", Cambridge University Press, Published for the Intergovernmental Panel on Climate Change.
- IRJ, International Railway Journal (2004), "High speed rail gets a boost", IRJ, February [www.railjournal.com/A/xthismonth.html (04/03/2004)].
- Jansson J. O. (1980), "A simple bus line model for optimisation of service frequency and bus size", *Journal of Transport Economics and Policy*, 14, 1, January, 53-88.
- Janić M. (1999), "Aviation and externalities: the accomplishments and problems", *Transportation Research Part D*, 4, 159-180.
- Janić M. (2000), "Air transport system analysis and modelling", Gordon and Breach Science Publishers, Amsterdam.
- Janić M. (2003a), "The potential for modal substitution", in: Upham P., Maughan J., Raper D., Thomas C. (Editors), "Towards sustainable aviation", Earthscan, London.
- Janić M. (2003b), "High-speed rail and air passenger transport: a comparison of the operational environmental performance", *Proceedings of the Institution of Mechanical Engineers Part F Journal of Rail and Rapid Transit*, 217, 259-269.
- Japan Railway & Transport Review (1994), "High-speed trains world wide", *Japan Railway & Transport Review*, 3, October, 0-2 and 63-65.
- Kasai Y. (2000), "A history of the development of Japanese railway networks", *Japan and the World Economy*, 12, 89-93.
- Klein M. (1993), "America's lost opportunity", in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire. Landing.com [www.landings.com (16/07/2003)].
- Layard R., Glaister S. (editors) (1994), "Cost-benefit analysis", Cambridge University Press, Cambridge.
- Le Blond P. (2003), email exchange with (former) Director of Strategy and Finance, Eurostar, October.
- LH, Lufthansa (2002), "Fly from Frankfurt. Take off from the center of Stuttgart", company brochure, received March 2002.
- LH, Lufthansa (2003), "Lufthansa InfoFlyway", LH [www.lufthansa.com/erodyn/fb_main.aero (21/04/2003)].
- Lijesen G. M., Rietveld P., Nijkamp P. (2001), "Fares of layover flights: the case of intercontinental flights from Europe", NECTAR conference No 6, Helsinki, Finland, 16-18 May.
- Lijesen G. M., Rietveld P., Nijkamp P. (2002), "How do carriers price connecting flights? Evidence from intercontinental flights from Europe" *Transportation Research Part E*, 38, 239-252.
- López-Pita A. (2003), "The effects of high-speed rail on the reduction of air traffic congestion", *Journal of Public Transportation*, 6, 1, 37-49.

- López-Pita A., Robusté F. (2004a), "High-speed line airport connections in Europe: state of the art study", Transportation Research Board (TRB), 83rd Annual Meeting, 11-15 January, Washington, DC, USA.
- López-Pita A., Robusté F. (2004b), "Impact of high-speed lines in relations with very high frequency air services", Transportation Research Board (TRB), 83rd Annual Meeting, 11-15 January, Washington, DC, USA.
- LTT, Local Transport Today (2002), "DfT says yes to monetary values for environment but not for jobs", LTT, 4 July, 6.
- Lyons G. (2003), "Future mobility – it's about time", 35th Annual UTSG Conference, Loughborough University, 6-8 January.
- Lythgoe W. F., Wardman M. (2002), "Demand for rail travel to and from airports", *Transportation*, 29, 125-143.
- Lu C. H. Y., Morrell P. (2001), "Evaluation and implications of environmental charges on commercial flights", *Transport Reviews*, 21, 3, 377-395.
- Mackie P. J., Jara-Diaz S., Fowkes A. S. (2001), "The value of travel time savings in evaluation", *Transportation Research Part E*, 37, 91-106.
- Maddison D., Pearce D., Johansson O., Calthrop E., Litman T., Verhoef E. (1996), "The true cost of road transport", Earthscan Publications Ltd, London.
- Masuda Y. (2003), "Japanese approach to high speed rail", presentation at The Centre for Transport Policy, Robert Gordon University conference on: Is High Speed Rail the way forward for Britain?, 7 July, Earls Court Conference Centre, London.
- Matsuda M. (1993), "Shinkansen: the Japanese dream", in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.
- Mayeres I., Ochelen S., Proost S. (1996), "The marginal external costs of urban transport", *Transportation research Part D*, 1, 2, 111-130.
- Mokhtarian P. L., Salomon I. (2001), "How derived is the demand for travel? Some conceptual and measurement considerations", *Transportation Research Part A*, 35, 695-719.
- Mott MacDonald (2003), "Key European hubs – comparison of aviation policy", Mott MacDonald, report to the House of Commons – Transport Select Committee, May [http://www.parliament.uk/parliamentary_committees/transport_committee/transport_committee_reports_and_publications.cfm (18/06/2003)].
- MVA Consultancy, Institute for Transport Studies at Leeds University, Transport Studies Unit at Oxford University (1994), "Time savings: research into the value of time" in: Layard R., Glaister S. (editors), "Cost-Benefit analysis", Cambridge University Press.
- Nash C., Rivera-Trujillo C. (2004), "Rail regulatory reform in Europe – principals and practice", paper presented at the STELLA/STAR Focus Group 5 meeting, Athens, Greece, 4-5 June.
- Navrud S. (2002), "The state-of-the-art on economic valuation of noise", Final report to the European Commission DG Environment, Department of Economics and Social Sciences, Agricultural University of Norway, 14 April [www.europa.eu.int/comm/environment/noise/020414noisereport.pdf (28/03/2004)].
- NERA, National Economic Research Associates (2004), "Study to assess the effects of different slot allocation schemes", A final report to the European Commission - DG TREN, NERA, January, London.
- Neufville R. D., Odoni A. (2003), "Airport systems", Aviation Week, London.
- Nielsen S. K. (2001), "Air travel, life style, energy use, and environmental impact", PhD Dissertation, Technical University of Denmark, Lyngby, September.
- Nijland H. A., Kempen Van E.E.M.M., Wee Van G. P., Jabben J. (2003), "Costs and benefits of noise abatement measures", *Transport Policy*, 10, 131-140.
- Nijkamp P., Blaas E. (1994), "Impact assessment and evaluation in transportation planning", Kluwer Academic Publishers, London.
- Nolan J. F., Ritchie P., Rowcroft J. (2004), "September 11 and the world airline financial crisis", *Transport Reviews*, 24, 2, 239-255.

- Noland B. R., Polak W. J. (2002), "Travel time variability: a review of theoretical and empirical issues", *Transport Reviews*, **22**, 1, 39-54.
- ODPM, Office of the Deputy Prime Minister (2001), "Planning policy guidance note 2: Green Belts", ODPM, July [www.planning.odpm.gov.uk/ppg/ppg2/01.htm (24/3/2003)].
- OEF, Oxford Economic Forecasting (1999), "The contribution of the aviation industry to the UK economy", Oxford Economic Forecasting, November.
- Okada H. (1994), "Features and economic and social effects of the Shinkansen", *Japan Railway & Transport Review*, **3**, October, 19-16.
- Opodo (2003) [<http://www.opodo.co.uk/> (25/08/2003)].
- Oum T. H., Hun Park J., Zhang A. (2000), "Globalization and strategic alliances – the case of the airline industry", Pergamon, Amsterdam.
- Pang S. (2003), "Strategic development of airport and rail infrastructure: the case of Singapore", *Transport Policy*, **10**, 27-33.
- Pavaux J. (1994), "Air-rail complementarity in Europe: lessons for intermodalism in America", paper presented at the TRB 73rd annual meeting, January 9-13, Washington DC.
- Pearce B., Pearce D. (2000), "Setting environmental taxes for aircraft: a case study of the UK", Centre for Social and Economic Research on the Global Environment (CSERGE), Working Paper GEC 2000-26.
- Pearce D. (2003), written evidence to the House of Commons Environmental Audit Committee, Appendix 8, Ev121-Ev126, in: House of Commons Environmental Audit Committee, "Budget 2003 and Aviation", Ninth report of session 2002-03, The Stationary Office, July.
- Perren B. (2001), "Special report: Paris-Marseille in three hours", *Modern Railways*, Ian Allan Publishing, July, 10.
- Polino M. N. (1993), "The TGV since 1976", in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.
- Price A. (1999), "The new approach to the appraisal of road projects in England", *Journal of Transport Economics and Policy*, **33**, 2, 221-226.
- Pronello C. (2003), "The measurement of train noise: a case study in northern Italy", *Transportation Research Part D*, **8**, 113-128.
- Quinet (1994), "The social cost of transport: evaluation and links with internalisation policies", in: OECD/ECMT, "Internalising the social costs of transport, OECD/ECMT seminar, Paris.
- Railway Age (2001), "Planes to the trains: coming to America?", *Railway Age*, January [http://www.railwayage.com/jan01/plnes_to_the_trains.html (13/07/2003)]
- Railway Gazette International (2004), "Heathrow connect close to takeoff", *Railway Gazette International*, June [www.Railwaygazette.com/2004/046-frp1.asp (29/07/2004)].
- Raoul J. C. (1997), "How high-speed trains make tracks", *Scientific American*, **227**, 4, 100-105 [<http://www.sciam.com/1097issue/1097raoul.html> (04/19/2002)].
- RCEP, Royal Commission on Environmental Pollution (2002), "The environmental effects of civil aircraft in flight", RCEP, November.
- Reynolds-Feighan A. J., Button K. J. (1999), "An assessment of the capacity and congestion levels at European airports", *Journal of Air Transport Management*, **5**, 113-134.
- Rietveld P. (2002), "Why railway passengers are more polluting in the peak than in the off peak: environmental effects of capacity management by railway companies under conditions of fluctuating demand", *Transportation Research Part D*, **7**, 347-356.
- Rietveld P., Brons M. (2001), "Quality of hub-and-spoke networks; the effects of timetable co-ordination on waiting time and rescheduling time", *Journal of Air Transport Management*, **7**, 241-249.

- Rietveld P., Bruinsma R. F., van Vuuren D. J. (2001), "Coping with unreliability in public transport chains: a case study for Netherlands", *Transportation Research Part A*, **35**, 539-559.
- Rossi P. H., Freeman H. E. (1993), "Evaluation: a systematic approach", SAGE, California, in: Giorgi L., Pearman A., Tandon A., Tsamboulas D., Reynaud C., (editors) (2002), "Project and policy evaluation in transport", Ashgate, Aldershot.
- Route Planner [www.europe.opel.com (13/03/2004)].
- SACTRA, Standing Advisory Committee on Trunk Road Assessment (1999), "Transport and the economy", DETR, August.
- Saito M. (1994), "Feasibility of High-Speed Railway in Asia and Oceania", *Japan Railway & Transport Review*, **3**, October, 40-44.
- Sands B. (1993a), "The German Inter City Express", *Built Environment*, **19**, 3/4, November, 203-214.
- Sands B. (1993b), "The development effects of high-speed rail stations and implications for Japan", *Built Environment*, **19**, 3/4, November, 257-284.
- Sayers T. M., Jessop A. T., Hills P. J. (2003), "Multi-criteria evaluation of transport options – flexible, transparent and user friendly?", *Transport Policy*, **10**, 95-105.
- Schafer A., Victor G. D. (2000), "The future mobility of the world population", *Transportation Research Part A*, **34**, 171-205.
- Schipper Y. (2000), "Market structure and environmental costs in aviation", Tinbergen Institute Research Series, Vrije Universiteit, Amsterdam.
- Schipper Y., Nijkamp P., Rietveld P. (1998), "Why do aircraft noise value estimates differ? A meta analysis", *Journal of Air Transport Management*, **4**, 117-124.
- Schobersberger W., Fries D., Mittermayer M., Innerhofer P., Sumann G., Schobersberger B., Klingler A., Stollnberger V., Fischbach U., Gunga H. C. (2003), "Changes of biochemical markers and functional tests for clot formation during long-haul flights", *Thrombosis Research*, **108**, 19-24.
- Sewill B. (2003), "The hidden cost of flying", Aviation Environment Federation, February [www.airportwatch.org.uk/publications/hidden%20cost%20final.pdf (10/3/2003)].
- Sharp A. (2002), "Rail-air replacement: problems and opportunities", Air-rail transfer seminar, Manchester Metropolitan University, 21 November.
- Sharp A. (2003), "No let-up in provision of new rail-air links", *International Railway Journal*, March.
- Shima H. (1994), "Birth of the Shinkansen – a memoir", *Japan Railway & Transport Review*, **3**, October, 45-48.
- Sone S. (1994), "Future of high-speed railways", *Japan Railway & Transport Review*, **3**, October, 4-8.
- Spiekermann K., Wegener M. (1994), "The shrinking continent: new time-space maps of Europe", *Environment and Planning B: Planning and Design*, **21**, 6, 653-673.
- SRA, Strategic Rail Authority (2003a), "The strategic plan 2003 – platform for progress", SRA, January [http://www.sra.gov.uk/publications/strategy/strategy_SRAs_Strategic_Plan_2003/strategic_plan_2003SRA_Plan1.pdf (11/05/2004)].
- SRA, Strategic Rail Authority (2003b), "Statement by SRA - the future development of air transport in the United Kingdom: South East", SRA, June.
- Staniland M. (2003), "Governments birds - Air transport and the state in Western Europe", Rowman & Littlefield Publishers, Oxford.
- Stead D. (2001), "European perspectives", *European Journal of Transport and Infrastructure Research*, **1**, 4, December, 415-418.
- Stubbs J., Jegede F. (1998), "The integration of rail and air transport in Britain", *Journal of Transport Geography*, **6**, 1, 53-67.
- Taniguchi M. (1993), "The Japanese magnetic levitation trains", *Built Environment*, **19**, 3/4, November, 235-243.

- TCRP, Transit Cooperative Research Program (2000), "Improving public transportation access to airports", Transportation Research Board - National Research Council, National Academy Press, Washington, D.C.
- TEST (1991), "Wrong side of the truck? Impacts of road and rail transport on the environment: a basis for discussion", TEST, London.
- The Group of Personal Representatives of the Head of State or Government (1995), "Trans-European networks" European Communities, Brussels.
- The Observer (2004), "Why slots sales are key to airlines' take-off", The Observer, 11 April [www.nera.com/_template.cfm?c=6168&o=6655 (16/04/2004)].
- Thomas C., Lever M. (2003), "Aircraft noise, community relations and stakeholder involvement" in: Upham P., Maughan J., Raper D., Thomas C. (Editors), "Towards sustainable aviation", Earthscan, London.
- Thompson I. B. (1995), "High-speed transport hubs and Eurocity status: the case of Lyon", Journal of Transport Geography, 3, 1, 29-37.
- Thompson L. S. (1994), "High Speed Rail (HSR) in the United State – why isn't there more?", Japan Railway & Transport Review, 3, October, 32-39.
- Thompson L. S. (2003), "Changing railway structure and ownership: is anything working?", Transport Reviews, 23, 3, 311-355.
- Tretheway W. M. (2004), "Distortions of airline revenues: why the network airline business model is broken", Journal of Air Transport Management, 1, 3-14.
- Turner B. (Editor) (2002), "The statesman's year book", Palgrave Publishers, Bath.
- UIC, International Union of Railways (2002), "High speed trains around the world", International Union of Railways, October.
- UIC, International Union of Railways (2003), UIC [www.uic.asso.fr (21/7/2003)].
- Uittenbogaart P. (1997), "Airline competition on the route between Amsterdam and London", Journal of Air Transport Management, 3, 4, 217-225.
- Union Railways (2000), "Channel Tunnel Rail Link - at a glance", Union Railways, March.
- Upham P., Maughan J., Raper D., Thomas C. (Editors) (2003), "Towards sustainable aviation", Earthscan, London.
- Vandermeer R. QC (2001), "The Heathrow Terminal Five and associated public inquiries - main report", Department for Transport, Local Government and the Regions, November [www.planning.dtlr.gov.uk/callins/terminal5/pdf/mainrep01.pdf and www.planning.dtlr.gov.uk/callins/terminal5/pdf/mainrep02.pdf (22/12/2001)].
- Viegas J. M., Blum U. (1993), "High speed railways in Europe", in: Banister D., Berechman J. (Editors), "Transport in a unified Europe", Elsevier Science Publishers, London.
- Waters II W. G. (1985), "Rail cost analysis", in: Button K. J., Pitfield D. E. (Editors), "International railway economics", Gower Publishing Company Limited, Aldershot.
- Wardman M. (2001a), "A review of British evidence on time and service quality valuations", Transportation Research Part E, 37, 107-128.
- Wardman M. (2001b), "UK value of time, working paper 4", Institute for Transport Studies, Leeds University.
- Wardman M., Waters II W. G. (2001), "Editorial - Advances in the valuation of travel time savings", Transportation Research Part E, 37, 85-90.
- Weinert W. (2002), "Air and rail – the limits of substitution", Air-rail transfer seminar, Manchester Metropolitan University, 21 November (*mimeo/presentation*).
- Welch M., Williams H. (1997), "The sensitivity of transport investment benefits to the evaluation of small travel-time savings", Journal of Transport Economics and Policy, 31, 231-254.
- Whitelegg J., Holzapfel H. (1993), "The conquest of distance by the destruction of time", in: Whitelegg J., Hultén S., Torbjörn F. (Editors), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.
- Whitelegg J., Hultén S., Torbjörn F. (Editors) (1993), "High speed trains fast tracks to the future", Leading Edge, North Yorkshire.

- Whitelegg J., Williams N., Evans C. (editor) (2001), "The plane truth: aviation and the environment", Transport 2000 and The Ashden Trust, [www.aet.org.uk/dbank.htm (23/3/2001)].
- Wickens D. C., Mavor S. A., Parasuraman R., McGee P. J. (editors) (1998), "The future of Air Traffic Control – human operators and automation", Panel on Human Factors in Air Traffic Control Automation, Commission on Behavioural and Social Sciences and Education National Research Council, National Academy Press, Washington, D.C.
- Williams G. (2001), "Will Europe's charter carriers be replaced by 'no-frills' scheduled airlines?", *Journal of Air Transport Management*, 7, 277-286.
- Wit R. C. N., Davidson M. D., Dings J. M. W. (2003), "Meeting external costs in the aviation industry", report for the Commission from Integrated Transport, CE Delft, Delft, August.
- Zembri P. (2003), "The spatial consequences of air transport deregulation: an overview of the French case since 1995", Paper presented at the NECTAR 7th Euroconference, 13-15 June, Umeå, Sweden.

Appendices

Appendix A: Analysis of delays in the European Air Transport Industry

Appendix B: The development of the High-Speed Train

Appendix C: The main pollutants and gases associated with aircraft and HST operation impact on local air pollution

Appendix D: Noise standards and the measurement of noise

Appendix E: Calculation of airport and ATC charges

Appendix A: Analysis of delays in the European Air Transport Industry

The main outcome of congestion is delays to air services, in other words “congestion expresses itself in delay” (Caves and Gosling, 1999: 60). “Anyone who is trying to travel by air in Europe knows that flight departure and arrival times do not mean anything anymore. Flight delays have reached overwhelming proportions and no end in sight” (ATAG, 1999). Button et al (1998) conclude that “even allowing for existing capacity and planned capacity expansions, the forecasts are in general agreement that the situation regarding airport capacity is not only difficult now, but will inevitably get worse as continued traffic growth takes place into the next century” (ibid: 79). Although the above quotes refer to the period prior to the September 11 events in the US and the subsequent fall in traffic, they remain relevant today. Even with the continuous reduction in traffic in 2002, which began after 11 September 2001, more than 10% of the flights in the European Civil Aviation Conference (ECAC) area were delayed on average for about 20 minutes (CODA, 2003). Considering that traffic is expected to recover (see section 2.1.4) and considering that other than at CDG and Schiphol no new runways will be available in the near future, delays to services are likely to increase again.

The Central Office for Delay Analysis (CODA), a service of the European Air Traffic Management Programme and part of Eurocontrol, is monitoring the delays to passenger services throughout Europe. This is the main source of information on delays to air services in Europe. The CODA measure of departure delay is based on the difference between the scheduled off block time and the calculated off block time taking into account slot time and estimated taxi time (CODA, 2003). The Block Time is the flight time between engines being switched on at departure and off on arrival (Doganis, 1992).

Table A1: Trend in main delay indicators in the ECAC region 1997-2002

Year	1997	1998	1999	2000	2001	2002
Total departures (thousands)	7,274	7,677	8,103	8,454	8,405	8,241
Delayed flights (%)	14.6	16.0	20.3	17.5	15.7	10.5
Avg. delay / movement (min.)	2.86	3.55	5.32	3.74	3.26	2.16
Avg. delay / delayed flights (min.) ¹	19.6	22.2	26.2	21.4	20.8	20.7

Source: CODA (2003), ¹ based on CODA (2003).

Table A1 shows the trend in the level of delays to passenger air services during 1997 - 2002. Throughout the period, air services were experiencing relatively high delays which, understandably, fluctuated in response to changes in traffic. To some extent, Table A1

presents the ability of the air transport system to cope and adjust to increases in traffic since there was no significant increase in the supply of infrastructure over these years. In 2002, the percentage of flights that were delayed in comparison with 1997, 1998 and 1999 was lower although traffic was higher. Considering the predicted growth in demand for air services, it seems inevitable that delays will further increase in the future.

Table A2: Comparison of delays to departure flights between different airports.

Image removed due to third party copyright

Source: CODA (1999; 2000; 2001; 2002; 2003).

Table A2 shows the trend in the level of delays to passenger air services during the last five years in major European airports and the London airports. It mainly demonstrates the extent of congestion at those airports where on average 23% of the departure services were delayed for an average of over 21 minutes during 1998-2002. There seems to be no rule that can be inferred from Table A2. The small London airports do not have systematically more or fewer delays than the larger airports, and the London airports do not have significantly more or fewer delays than the other European airports. The fact that there is no difference between small and large airports can either suggest that they all have runway capacity shortage or that they are all influenced by the same lack of ATC capacity over the European skies. There is also no evidence in the CODA data that short haul flights are likely to be delayed more or less than long haul flights.

Table A3: Causes of delays in the air industry, by IATA Category for 2000 - 2002.

Cause	2000	2001	2002
Airline	41%	41%	47%
En-Route	35%	29%	19%
Airport	14%	15%	16%
Security	3%	6%	18%
Weather	7%	9%	
Total	100%	100%	100%

Source: CODA (2001; 2002; 2003).

Table A3 provides information on the main causes of delays in the period 2000-2002 (since CODA presentation of delay causes changed in 2000, a comparison with 1998 and 1999 was

not possible). Only the Airport and the En-Route categories can be directly associated with lack of capacity. It can then be concluded that: in 2000 about 49% of the delays were directly related to capacity shortage, with the rest of the delays not related directly to capacity shortage but to operational problems. The amount of delay associated with capacity shortage decreased to 44% and 35% in 2001 and 2002 respectively, but it remained significant.

A1: Congestion on the case study route

The CODA reports provide also information on the level of delays on the case study route, London to Paris in general and Heathrow to CDG airports in particular.

In 2002, in the most affected (by delays) and most dense traffic flows table the London airports appeared as departure or destination in 6 out of the 10 traffic flows. Traffic from or to the UK & Ireland (including the London airports as departure or destination) appeared in the table in **all 10 traffic flows**. Furthermore, the third traffic flow in Europe, when ranked by average delay per movement, was from UK & Ireland to Paris airports (CODA, 2003).

Considering the congestion in the skies over Europe, where the main reason for the delays to air traffic services in 2002 was “a lack of ATC capacity” (CODA, 2003: 8), and within and around the London and Paris airports, flights between London and Paris that can be served by HST can be seen as a waste of valuable ‘air’ capacity. In 2001, 21,752 flights were operated between Heathrow and CDG airports (CODA, 2002) these flights represented 4.2% and 4.7% of the total ATM for 2001 in CDG and Heathrow respectively.

The high frequency of flights between Heathrow and CDG contributed to congestion and delays at the airports and to the services between them by affecting the congestion in the airports and in the air. At least 20% of the services on the route were delayed during each year between 1999 and 2002, slightly higher than the overall percentage of flights delayed at Heathrow (Tables A4 and A5) and these figures were generally higher than the figures for Europe as a whole in 2002 (10.45% flights delayed for 20.66 minutes on average in 2002 (CODA, 2003)).

Table A4: Number of flights from Heathrow to CDG airport and level of delays on the route.

Image removed due to third party copyright

Source: CODA (2000; 2001; 2002; 2003)

Table A5: Number of departure flights and level of delays at Heathrow airport.

Image removed due to third party copyright

Source: CODA (2000; 2001; 2002; 2003).

A2: Conclusions

The main conclusions that can be drawn from the short analysis are as follow. First, passenger air services in Europe experience substantial delays that are affecting many if not all the European airports. Furthermore, the level of delays is substantial considering that about 20 percent of the flights (although less for 2002) in the sample airports are delayed by around 20 minutes. Some of these flights, for example between Heahtorw and CDG, are scheduled to take just over one hour. Second, it is not possible to infer from the data in which airports, and to what degree, runway or ATC capacity shortage is the main reason for delay, and in which airports delays occur only as a result of delays in other airports. Third, there is a problem with the way delays are measured since it allows airlines to reduce delays over time by increasing the schedule flight time. A report in Airline Business states that “insofar as they [delays] are foreseen, airlines include them as a buffer in the timetable...For example, an analysis of British Airways schedule for summer 2001 shows how allowed times have crept up at congested Heathrow. Time allowed was up by 12% on the Glasgow route, compared with summer 1989; up 14% to CDG since 1979. Over the same time, the rise on the route from London Gatwick to Frankfurt was up by a third” (Airline Business, 2002: 69). However, there is no better or other source of information to analyse delays to air services. Nevertheless, the picture emerging is still one of severe delays and disruption to services, which has implications for passengers, airlines, airports and the environment.

Appendix B: The development of the HST

It is the development of the HST, which makes the train a viable alternative to the aircraft. This appendix illustrates the development of the HST and how it evolved to be the main competitor to the aircraft on some routes, and potentially a replacement to airlines' aircraft services on some routes.

B.1 The evolution of the present High Speed Train

On October 1, 1964 the first HST passenger service, on the 560 km Tokaido line between Tokyo and Osaka, was launched with trains running at speeds of 210 kph. This date marks the beginning of the modern HST era. Since then the network of HST has expanded, first in Japan, and later in other countries, and the speed has increased.

Today's HST uses the same basic technology of steel wheel on steel rail as the first trains did at the beginning of the 19th century. However, many incremental engineering and technological developments were required in all aspects of train operation to allow trains to run commercially at speeds higher than 200 kph. Already during the 1950s it was apparent to engineers that by using more power they could make conventional trains reach speeds of over 330 kph, but this was not enough for commercial high speed services. "The higher speeds were deemed infeasible for commercial application because the fast-moving vehicles damaged the tracks severely. High speed trains, it seemed, would have demanded extensive, and thus prohibitively expensive, track maintenance efforts" (Raoul, 1997: 100). In addition, the increase in the centrifugal forces as train's speed increases when running through curved sections led to passenger discomfort. Furthermore, it is not enough that the train is capable of running at high speed but it is also essential that the track supports trains running at high speeds³⁵².

The main technical challenge, therefore, was to develop a train and track that could, while the train is running at high speed, maintain stability and comfort for the passengers, maintain the ability to stop safely, avoid a sharp increase in (train) operating costs and (track) maintenance costs, and avoid an increase in noise and vibration to the areas adjacent to the line. The solution included, in most cases:

- Building tracks that avoid tight curves and steep grades.

³⁵² This might explain the term High Speed Rail (HSR), often used to describe HST, in addition to the fact that train and rail (or railway) are often used synonymously.

- Increasing the distance between axles in the bogies³⁵³ to help maintain stability.
- Placing the bogies between carriages, and not at the end of each carriage, to reduce weight by halving the number of bogies required to carry the carriages.
- Improving stability, by preventing the cars from pivoting away from one another on curves.
- Designing aerodynamic trains to reduce drag, and shaping the train in a way that reduces the noise and vibration it induces.
- Using lighter and stronger materials (ibid).

The principle of HST services is defined by some as being “twice as fast as the auto, half as expensive as air” (Sands, 1993a: 205)³⁵⁴. Another definition for HST is “to provide the transport services to its users (passengers) at the speed twice higher than a car and twice slower than the plane” (EC, 1996: 88). In both definitions, speed is central, and indeed it is the speed feature of the modern train that has brought back the glory it once had and that was lost (mainly) to the car. The maximum speed of the Shinkansen (‘new trunk line’ in Japanese and the name given to the Japanese HSTs) remained at 210 kph for a long period, mainly because of noise problems. At present, maximum speed throughout the Tokaido line has been raised to 270 kph (Central Japan Railway Company, 2003)³⁵⁵. The French HST, Train à Grande Vitesse (TGV), began operation in 1981 between Paris and Lyon, reaching a maximum speed of 260 kph. Eight years later, when another line of the TGV network, the Atlantique line, was opened, trains were able to reach a commercial maximum speed of 300 kph (Japan Railway & Transport Review, 1994). Today, the standard has been raised further to 350 kph, which is the official maximum operating speed of new HST lines like the TGV Méditerranée and the Madrid – Barcelona line (under construction) (UIC, 2003). Tests show that much higher maximum speeds can be reached³⁵⁶, but such speeds seem commercially unfeasible at present due to noise problems, high operating costs, and other technical problems.

There is no single definition for high speed in the context of rail services. High speed can relate to the infrastructure capability to support high speed, the rolling stock capability to achieve high speed, and/or the actual operation speed achieved. The EU definition, given in Directive 96/48, is 250 kph for dedicated new lines, and 200 kph for upgraded lines in

³⁵³ Bogies, also called trucks, “consist of two or more pairs of wheels and their axels connected by a frame that supports the cars [termed carriages in the UK] above” (Raoul, 1997).

³⁵⁴ However, most evidence, for example from Eurostar services between London and Paris or Brussels, suggests that the HST is at least as expensive, and often more expensive, than aircraft.

³⁵⁵ However, it is higher on the Osaka to Hiroshima line.

³⁵⁶ While the 200 kph barrier was broken in Germany as early as 1903, the French achieved a record of 331 kph in 1955, and currently hold the record, for a steel wheel on steel rail train, of 515 kph, achieved in 1990 by a modified TGV-Atlantique train (Whitelegg et al, 1993).

respect of the infrastructure capabilities. The same applies to the rolling stock (on specially built and upgraded lines respectively), with 300 kph defined as high speed in 'appropriate circumstances'. With some TGV, Eurostar and Shinkansen trains capable of operating speeds of 350 kph, 300 kph seems a more appropriate minimum for services to be defined as 'true' HST. However, such a definition will leave out the Tokaido Shinkansen HST which, although operating at 270 kph max speed, is certainly a HST service.

In the context of this research, it is travel time by HST that is of concern, and therefore the average, rather than the maximum, speed is of importance. Average speed, start to end, is always significantly lower than the maximum speed and is mainly affected by the number of stops on the route and the different speed restrictions along the route. The benchmark for average travel speed can be the TGV Méditerranée line. According to the timetable, a journey from Paris to Marseille (750 km) would run at 250 kph (Perren, 2001). For comparison, the current average speed between London and Paris (495 km) is about 165 kph, but will increase to around 220 kph once the Channel Tunnel Rail Link (CTRL) opens.

B.1.1 The main models of HST

HST lines and services are suitable, and can be commercially justified, in special circumstances and therefore on specific routes only. These characteristics are mainly concerned with the route distance, and the level of demand for travel on the route. Based on the route characteristics, three main models, or prototypes, of HST have been developed and are operational, while a fourth is still under development.

The Japanese Shinkansen, being the first HST in operation, is considered here as the base model of HST. Its main features evolved from Japan's unique characteristics, apparent on the Tokaido line. These include large metropolitan centres (Japan's biggest cities Tokyo, Osaka, and Nagoya with approximately 30, 16, and 8.5 million people respectively), located a few hundred km apart from each other (Tokyo – Osaka 560 km with Nagoya located on the route 342 km from Tokyo), and high demand for travel between them (enough to support 287 daily services between Tokyo and Osaka in 2003 (Central Japan Railway Company, 2003)). Another feature of the Shinkansen is a newly built dedicated line, which in the case of Japan was required since most of the conventional tracks in the Japanese network are narrow gauge and cannot support HST. This completely isolates the Shinkansen services from the rest of Japan's rail system. The geographic features of Japan in general and specifically between Tokyo and Osaka, together with the requirement to avoid tight curves and steep gradients, to allow for high speeds, resulted in numerous tunnels and bridges along the route, which is typical of the Shinkansen lines. 30% of the Japanese Shinkansen lines run through tunnels

(Okada, 1994), and this leads to very high construction costs. Furthermore, the construction of a new line for the Shinkansen that runs into the city centres also exacerbates construction costs due to the high land values in city centres³⁵⁷.

The French TGV resembles the Shinkansen in purpose but differs in design philosophy. The differences are attributable to some extent to overcoming the disadvantages of the Shinkansen, and in a way the TGV was developed by learning the lessons of the Shinkansen (Sone, 1994). Some of the modifications were possible due to the different physical characteristics of France and Japan. The most significant difference between the TGV and the Shinkansen is probably the ability of the former to operate on conventional tracks as well, which allows the TGV to use the conventional lines as it enters and leaves the city centre. This means immense cost savings by avoiding the construction of a dedicated line through to the city centre station, which is usually the most expensive part due to high land prices and engineering complexity. It also means that the HST can serve parts of the network before the HST line is constructed, and/or in parts of the network where at present the demand is not high enough to justify the construction of a dedicated line (Bouley, 1986). Such through operation, or compatibility (with the conventional rail network), is not possible for Shinkansen trains.

Further reductions in construction costs were achieved on the TGV lines by avoiding the need for tunnels and bridges (and almost eliminating them from the Sud-Est line). This was made possible by enabling the train to run on steep grades of up to 3.5% (compared to 1.5% for the Shinkansen), and due to the different geomorphologic characteristics of France compared to Japan (Sone, 1994). Other improvements to the TGV involve different engineering modifications, mainly to reduce maintenance costs and improve the riding comfort for passengers. This includes the use of articulated carriages which reduce the number of bogies, as outlined above, and the use of shorter trainsets that can be coupled together to arrive at the high capacity of the Shinkansen trains while maintaining some operational flexibility with regard to train capacity (ibid).

The Spanish HST, the AVE (Alta Velocidad Espanola, or Spanish High Speed), first operated in 1992 between Madrid and Seville resembles in many features the TGV model³⁵⁸, but like the Shinkansen it uses a dedicated line throughout the route. The reason is that in Spain the conventional network is wider than the standard UIC gauge used across most of

³⁵⁷ Despite the high construction costs, no government subsidy was provided for the construction of the Tokaido line, and it took only 8 years to recoup the initial investment (Kasai, 2000). The line has been profitable ever since 1966 (Saito, 1994).

³⁵⁸ The rolling stocks are French-made and are basically the same model as the TGV Atlantique trains (Japan Railway & Transport Review, 1994).

Europe and the decision to build the AVE on the standard gauge was to allow it to connect with the emerging European, and mainly the French, HST network³⁵⁹ (Gómez-Mendoza, 1993). Also the ICE (Inter-City Express), Germany's HST, first operated in 1991, follows the TGV model of HST, mainly in the compatibility feature. But it deviates from the TGV and the Shinkansen models by adopting a mixed use line, which means the HST line is used for both passenger and freight transport³⁶⁰ (Bouley, 1986). This turned out to be a disadvantage rather than an advantage since it led to high construction costs (to support the higher load of freight trains) and low utilisation of the lines (since freight trains operate at much lower speeds). To begin with, the German ICE trains could only be used in Germany (see Aberle, 1993), but are now in operation in Belgium and the Netherlands.

All the above HSTs, the Japanese, French, Spanish and German trains, use a newly built track on sections where high speed is achieved, which translates into high investment costs. On routes where demand is high and current route capacity exhausted, these investments can be justified. However, on many routes traffic is not high enough to justify the cost of constructing new tracks that allows high speed. This problem was solved by a new model of HST, the tilting train, but at the price of lower speeds. To allow higher speeds on conventional lines with tight curves, the train tilts as it goes through curves. By simply tilting the train in tight radius curves (although by a very complicated mechanism), the discomfort passengers feel from the centrifugal force as the train goes at high speed through curves is solved; "the bogies remain firmly attached to the rails while the body of the carriage tilts, and so compensates for centrifugal force" (Giuntini, 1993: 61). This principle is adopted by many countries as a cheap alternative to the TGV and Shinkansen models of HST. The Swedish X-2000, and the Italian Pendolino (ETR-450), are examples of HSTs running on conventional rail using the tilting mechanism, and thus avoiding the price of expensive new tracks, but reaching maximum speed of only 210 kph (X-200) or 250 kph (ETR-450) (UIC, 2003).

If the tilting train form of HST described above is considered a downgrade, certainly in terms of speed, from the Shinkansen and TGV models of HST, the MAGLEV model of HST is considered an upgrade. The MAGLEV (short for 'Magnetic Levitation') technology was developed long ago but has never been in commercial operation on long distance routes. The technology relies on electromagnetic forces to cause the vehicle to hover above the track and move forward at theoretically unlimited speeds. In practice, the aim is for an operation speed

³⁵⁹ The go ahead for the first AVE line was given in 1986 and later it was decided to extend the standard gauge to the entire railway network (Gómez-Mendoza, 1993).

³⁶⁰ Italy also opted for mixed use on its HST lines (Bouley, 1986).

of 500 kph, a speed that has been achieved in tests³⁶¹ (Taniguchi, 1993). The MAGLEV is mostly associated with countries like Japan and Germany where MAGLEV test lines are in operation. In Japan, the test line will eventually be part of the Chuo Shinkansen between Tokyo and Osaka. MAGLEV trains on this line are expected to reduce the travel time between the cities to one hour from two and a half hours today. In recent years, China has been also associated with MAGLEV projects. In December 2003, a MAGLEV line between Shanghai airport and the city's Pudong financial district has been opened³⁶², but plans to adopt MAGLEV technology for the planned Beijing-Shanghai route are increasingly likely to be replaced in favour of a conventional steel wheel on steel rail HST (IRJ, 2004). In the context of this research, a commercial MAGLEV route can serve better as a substitute for aircraft. Since there is no such system in operation at present, this research will focus on conventional steel wheel on steel rail HST.

Figure B1: The 4 models of HSTs in terms of operating speed, construction cost, and compatibility with the conventional network

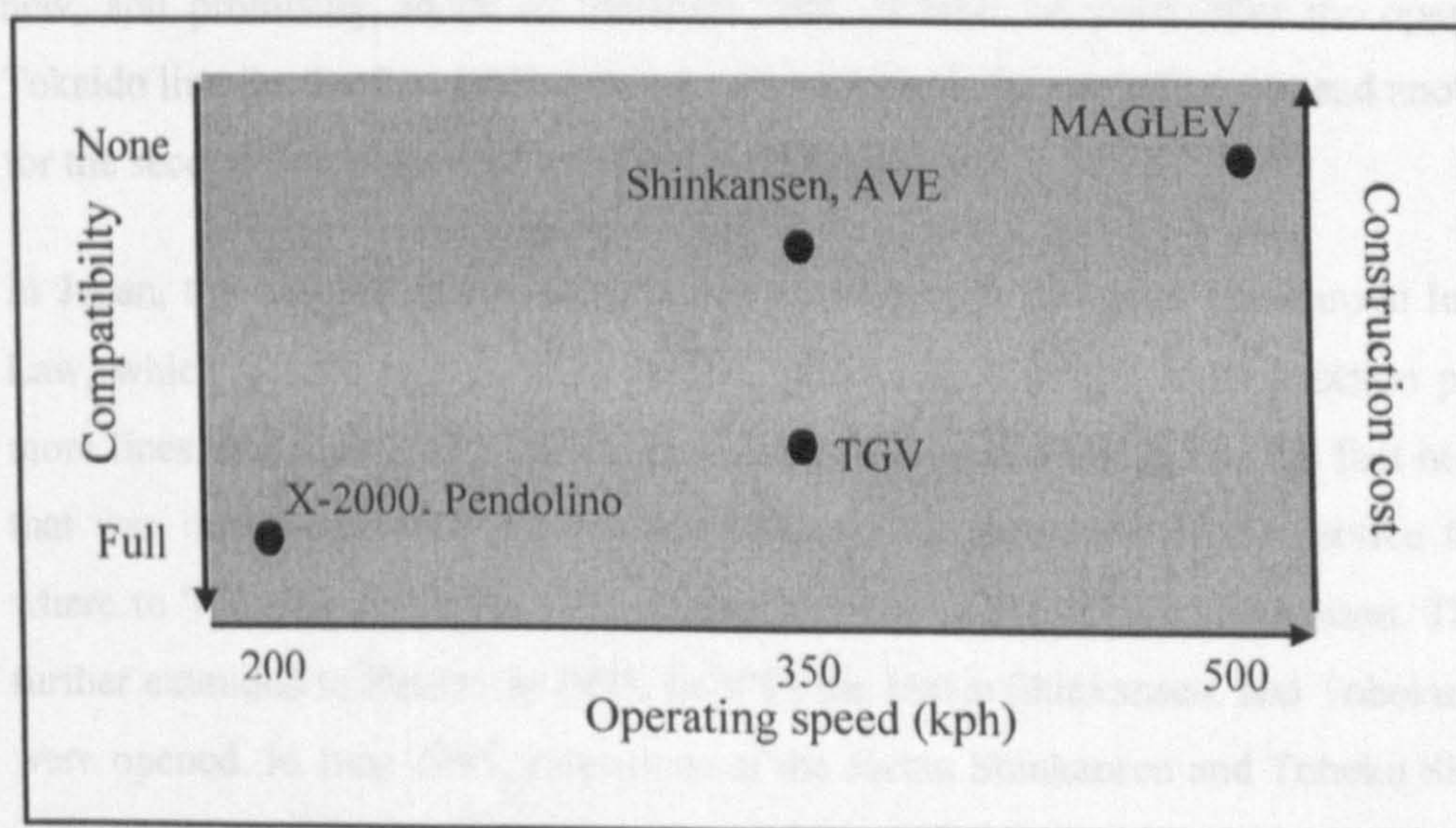


Figure B1 illustrates the main differences between the models of HST in terms of maximum operating speed, compatibility with the conventional network, and construction costs. The MAGLEV model of HST is expected to reach a much higher operating speed than the current TGV and Shinkansen, and it is built in complete isolation from the conventional rail network using a completely different technology from the other models of HST. Therefore, it has no compatibility with the conventional rail network and high construction costs. The Shinkansen and the TGV can achieve similar maximum operating speeds, but they differ in their level of compatibility with the rest of the rail network. The Shinkansen operates entirely

³⁶¹ In 1979 an unmanned Japanese MAGLEV reached 517 kph (Japan Railway & Transport Review, 1994).

³⁶² The trains operate at a maximum speed of 430 kph.

on a dedicated network while the TGV uses the conventional network in parts and this leads, amongst other things, to lower construction costs. The Shinkansen has, in potential, some degree of compatibility since it uses the conventional technology of steel wheel on steel rail, but it cannot use the conventional Japanese rail network since this network uses a narrower gauge. When HST can operate on conventional tracks, it can serve entire regions and destinations beyond the HST line, thus providing an extensive area service. The tilting train model of HST, represented in Figure B1 by the Swedish X-2000, uses the conventional network, but usually still requires an upgrade of the existing line before operation. It is the cheapest to construct, and the slowest model of HST, but it has full compatibility with the conventional network.

B.2 The development of the HST network

The tremendous and very fast success of the Tokaido line in Japan, in terms of ridership and profits, but mainly in terms of the technological achievement, boosted the HST role as a new, and promising, mode of transport. Still, it took 17 years after the opening of the Tokaido line for the first HST to be introduced outside Japan (in France) and another 7 years for the second European HST to begin service in Italy.

In Japan, the success of the Tokaido line prompted the National Shinkansen Improvement Law, which was passed in 1970, leading to the approval of the construction plan for two more lines: the Joetsu, and Tohoku Shinkansen (Matsuda, 1993). But the first new HST line that was introduced after the Tokaido line was the extension of the service from Osaka, where the Tokaido line ends, to Okayama in 1972 on the Sanyo Shinkansen. This line was further extended to Hakata in 1975. In 1983 the Joetsu Shinkansen, and Tohoku Shinkansen were opened. In June 1991, extensions of the Joetsu Shinkansen and Tohoku Shinkansen to Tokyo were opened and Japan's four HST lines were connected together to form the Japanese HST network. This network consists today of 2,175 km of HST line in operation, with a further 215 km under construction, and 349 km at the planning stage (UIC, 2003).

The first HST line outside Japan was opened in France, between Paris and Lyon in 1981, and this also proved to be a success story, and in turn the driving force behind the expansion of the HST in France. Already in 1981 plans for construction of the new Atlantique TGV line were announced with works starting in 1987 (the line opened in 1990), but it was studies to evaluate the performance and impact of the Paris – Lyon line, carried out between 1983-1985, that led the French Government, in 1987, to decide on building a real TGV network through the construction of a line north to Paris (TGV Nord), the interconnection HST link around Paris (TGV Interconnexion), and extension of the TGV Sud-Est to Valence, south of

Lyon (Polino, 1993). Future plans for the French HST network include connections with all the neighbouring countries. At present, the French HST network consists of 1,541 km of HST lines in operation, 320 km under construction, and another 937 km at the planning stage (UIC 2003).

The development of the French HST network, with the vision to connect it to neighbouring countries, merged well with the EU strategy, formed several years later, to create a European HST network, as well as with the introduction of HST services in other European countries. The development of Europe's HST network is described in detail below.

While Europe seems to have taken a leading role in developing the HST network, certainly in terms of network size, the US is lagging behind without even one dedicated HST line in operation, and only one tilting train line between Boston and Washington. This is surprising considering that many transport corridors in the US suit the requirements for HST lines in terms of distance and city population size³⁶³. Elsewhere in the world, mainly in Asia, HST lines are built or are at least in advanced planning stages. This includes a 1,300 km HST line between Beijing and Shanghai in China, a 432 km HST line between Seoul and Pusan in South-Korea, and a 340 km HST line between Taipei and Kaohsiung in Taiwan (UIC, 2003).

Currently, the world HST network consists of 5,214 km of lines in operation, an additional 2,996 km under construction, and 4,238 km in different planning stages (ibid). The HST lines in operation are all within Europe (58% of the lines), and Japan (42%). 64% of the HST lines under construction or in the planning stage are within Europe, 1% in Japan and the rest in Asia (29%). If, and when, this world network of HST is completed, 61% of the world HST network will be in Europe, 22% in Japan, and 17% within Asia (ibid)³⁶⁴.

B.2.1 The development of Europe's HST network

The high speed achieved by the TGV and the likes in Europe is restricted to parts where suitable infrastructure has been supplied. Therefore, expanding the HST services in Europe can come only from the expansion of HST infrastructure. Europe's HST network is, and will remain in the future, the largest HST network in the world and the only HST system in the world that will evolve into a true HST network rather than a single line or a collection of HST lines.

For several reasons, Europe makes a good case for aircraft and HST substitution. The main reasons include the plans for the European HST network (important parts of which are

³⁶³ See Klein (1993) and Thompson (1994) for an account of the USA HST network.

³⁶⁴ The UIC (2003) web site does not quote any planned HST projects in the US although few lines are known to be planned, for example on the San-Francisco - Los-Angeles corridor.

already completed), and the current capacity shortage faced by the ATI. The dominance of H&S operation in most of the heavily congested airports further increases the potential for aircraft and HST substitution, but through cooperation and not competition, between the modes³⁶⁵. This merits special attention to the development of the European HST network.

Despite the successful introduction of HST in France in 1981 the spread of the HST across Europe was slow. It took 7 more years for the next European HST to be introduced. In 1988, the Italians introduced the Pendolino tilting train (ETR-450 model) on the Rome – Milan route and then on other routes³⁶⁶. Two years later, Sweden introduced its first HST, the X-2000, also a tilting-train model of HST. Next, in 1991, it was Germany's turn to introduce the ICE (Inter City Express) HST between Hamburg and Munich on the German HST network, which is a mix of new and upgraded lines. A year later, in 1992, Spain introduced its first HST service, the AVE, between Seville and Madrid. All these countries expanded their HST services since the introduction of the first HST service (the latest addition being the Spanish HST line between Madrid and Lerida). In the UK, the first HST line is scheduled for completion in 2007. The first section of this line connecting London with the Channel Tunnel was opened during 2003.

At the time when the above countries were pursuing, independently, their HST plans, and France was pursuing the expansion of its HST network to neighbouring countries, the European Union (EU) was emerging, and with it the idea of Trans-European Networks. "It made little sense to talk of a big market, with freedom of movement within it for goods, persons and services, unless the various regions and national networks making up that market were properly linked by modern and efficient infrastructure" (EC, 2001). Therefore the EU appointed The Group of Personal Representatives of the Heads of States or Government (Known as the Christophersen group) to "assist in implementing efficiently, consistently, and speedily the Trans-European networks in transport and energy" (The Group of Personal Representatives of the Head of State or Government, 1995: 10). The group's main task was to identify and recommend projects of priority importance and of common interest to the member states in the Trans-European Network (TEN). The first criterion for common interest was defined as "the completion of the connections, key links and interconnections needed to eliminate bottlenecks, fill in missing links and complete major routes" (ibid: 35). The group was also ordered to draft a master plan for the European network of high speed railways, and this was envisaged by the group to consist of "9,000

³⁶⁵ A H&S operation is considered an important element for successful airline and railway integration, as explained in section 2.3.3.

³⁶⁶ The ETR-450 is considered to be the first Italian HST. However, already in 1976 the first type of the Pendolino train entered service on the line between Ancona and Rome. This train could travel at a maximum speed of 250 kph (Giuntini, 1993).

kilometres of new lines, 15,000 kilometres of refurbished lines, and 1,200 kilometres of connecting lines. In addition the whole of the electrified railway track of the EC will be accessible to the high speed trains” (Viegas and Blum, 1993: 78).

Table B1: HST projects in the TEN-T priority projects

Image removed due to third party copyright

Source: European Communities (2002).

A boost to the emerging European HST network came when the 1992 Maastricht Treaty recognised the importance of setting up the Trans-European Transport Network; and when,

**DIAGRAM ON THIS
PAGE EXCLUDED
UNDER INSTRUCTION
FROM THE
UNIVERSITY**

in 1994, 14 transport priority projects, which were recommended by the group, were adopted and approved by the Essen European Council (European Communities, 2003). These projects became the Trans - European Transport Network priority projects, known as the TEN-T projects. Out of the 14 projects, six are defined as HST projects (projects 1-4, 6, and 14 in Table B1) and only three do not involve rail at all (EC, 2001).

In September 2001 the EU published a White Paper “European Transport policy for 2010: time to decide” that emphasized the role of the HST in the EU transport policy. One of the measures proposed in the White Paper is the completion of ‘missing links’, and particularly the trans-European high speed passenger rail network (CEC, 2001). As a result, the Barcelona European Council, later that year, strengthened the priority given to the 14 projects, and added six new projects, including one HST project, and one to allow interoperability of HST on conventional railways (Table B1 projects 17 and 19 respectively). Of the six new projects, only one does not include railway infrastructure at all (European Communities, 2002).

Figure B2: The planned European HST network.

Source: UIC (2003).

The TEN-T HST projects, together with the existing and planned HST lines in each member country (which are not part of the TEN-T), provide a relatively wide coverage of the EU and its major cities. This emerging network (outlined in Figure B2) is a prerequisite for a significant substitution between aircraft and HST to take place within Europe. However, the

success, and further expansion of the HST network, in Europe as well as elsewhere, depends on the impact of the HST first in terms of time savings, and improved accessibility, and then in terms of wider impacts as described in the next section.

B.3 The impact of the HST

The main purpose in introducing a HST service on a specific route is usually twofold. One is to increase the capacity of transport services on the route, which almost always means increasing the capacity of existing rail services³⁶⁷, and the other is to reduce travel time on the route. All HST lines, by definition, fulfil these purposes when cities served by the HST line are considered.

Spiekermann and Wegener (1994) created time-space maps of Europe that show the effect of reduced travel time on distances within Europe (Figure B3). The maps are based on the European rail network and train travel time in 1993, and in 2010 after the implementation of the HST network as envisaged by the International Union of Railway (Figure B2). The impact is best described by the title of the paper: “The shrinking continent” (ibid).

Before the inauguration of the HST in Japan, it took 7 hours to travel between Tokyo and Osaka on the conventional line. With the opening of the Tokido line in 1964 this was reduced to only 4 hours. Further improvements to the line and trains reduced the travel time between the cities to 2h30 in 1992 (Masuda, 2003), and this is the present travel time. Assuming that 85% of the total passengers on the four Shinkansen lines were shifted from conventional lines, then the annual time saved, calculated from the difference in schedule times between the Shinkansen and conventional lines, is estimated at approximately 400 million hours. The reduction in travel time also has an economic value³⁶⁸, and this was estimated at ¥500 billion (approximately €3.7 billion) per year (Okada, 1994). The opening of the Spanish HST between Madrid and Seville reduced travel time from 6h30m to 2h32m, making total journey time comparable with air (EC, 1996).

New HST lines provide increase capacity on the route since they usually provide additional services that supplement existing ones. The increase in capacity is also due to higher frequency, feasible in part due to the higher speed; the most up to date signalling systems, which allow relatively short headway between trains; and the fact that HST are usually long

³⁶⁷ In this sense the London to Paris and London to Brussels HST line is an exception since it is not supplementing an existing railway services between the cities, but a newly built railway route.

³⁶⁸ See section 3.3.

**DIAGRAM ON THIS
PAGE EXCLUDED
UNDER INSTRUCTION
FROM THE
UNIVERSITY**

trains with capacities of over 300 seats and, in some models, much more³⁶⁹. Higher frequency, due to higher speed and improved signalling, means that also the introduction of tilting trains on existing tracks is likely to lead to increased capacity on the route.

Figure B3: Time-space map of the rail network in Western Europe: (a) 1991 and (b) 2010

(b)
Source: Spiekermann and Wegener (1994: 669)

Shorter travel times and increased level of service following the introduction of HST have resulted in demand shifting to the HST from the car and aircraft modes, but also in the

³⁶⁹ The capacity of the Eurostar trains is 766 seats (Eurostar, 2003a), the Shinkansen 0 series: 1340 seats, the 500 series: 545, the TGV Atlantique: 485 seats (UIC, 2003), and in addition two TGV trainsets can usually be coupled together.

generation of new traffic³⁷⁰. Table B2 shows the change in modal split following the introduction of HST on two routes Paris – Lyon and Madrid – Seville. On both routes, most of the demand has shifted to the train mode from the aircraft. On both routes, the increase in total traffic was substantial, most of it related to induced traffic (Table B2). Similar shifts occurred on the Sanyo Shinkansen HST line, where 23% of the traffic on the new line was diverted from the aircraft (Sands, 1993b). On the same line, 55% of the traffic was diverted to the new line from other rail lines, and 6% was induced traffic (ibid), which means 16% was diverted from the car and bus.

Table B2: Modal split before and after the introduction of HST services (Percentage)

Image removed due to third party copyright

Source: EC (1996).

The construction of HST lines, and the introduction of HST services, is also associated with other effects, mainly economic development at different spatial levels, ranging from the regional level, through the city level, and down to the station level.

Sands (1993b) summarises the effects of the Shinkansen in Japan and claims that “the Shinkansen has had strong development effects in Japan at the regional, urban and station levels” (ibid: 267). However, while regions served by Shinkansen achieved higher population and employment growth rates than those without direct Shinkansen services, there are other factors prevailing in these regions that can support and affect such an impact. Therefore, it is not clear if the Shinkansen led to the increase in growth rates or if the Shinkansen was constructed in regions where higher growth rates already existed. “At the Urban level, the Shinkansen’s correlation with population and employment growth rates is clear [but it seems that] the Shinkansen has served to shift growth, not induce it...[and] at the station level, development has varied” (ibid: 268). In situations where existing stations were expanded to accommodate the Shinkansen services, little or no development around the station occurred, while in new stations development was dependent on other factors and mainly good transportation links to the new station (ibid).

³⁷⁰ This phenomenon is often termed induced demand, induced traffic (e.g. SACTRA, 1999), or induced travel (e.g. Abelson and Hensher, 2001).

In France, following the opening of the Paris – Lyon HST line, Bonnafous (1987) cites changes in modal share, traffic volume, and changes in travel behaviour. Ampe (1995) notes that “TGV towns do not benefit automatically from having a TGV station, but that a strategy has to be developed to take advantage of the opportunities offered by improved transport links” (ibid: 130). In the case of Lyon, “the commercial and technical success of TGV was a disincentive for head offices to relocate in Lyon, given that Paris became accessible within a normal working day” (Thompson, 1995: 30, my emphasis).

Evidence from different studies on the effect of HST is mixed and the conclusion is often that the impacts of introducing HST services (other than the impacts of reduced travel time, and change in the traffic volume) are dependent on other prevailing conditions. In other words, the introduction of HST alone will not necessarily result in wider impacts other than reduced travel time. Banister and Berechman (2000) arrived at a similar conclusion with regard to economic development following investments in transport infrastructure. They conclude that “transport investment acts as a complement to other more important underlying conditions, which must also be met if further economic development is to take place” (ibid: 318).

Positive impacts associated with the introduction of HST services occur at places served by a HST station, yet in places bypassed by the HST line the impact seem to be, in general, negative. “High speed infrastructure connects only important cities, but not the space in between them. This generalisation hides the fact that the regions in between might become new peripheralised zones, in which accessibility is decreasing in relative or even absolute terms through the elimination of interim stops, when high speed trains are introduced” (Spiekermann and Wegener, 1994: 671). Bruinsma and Rietveld (1993) analysed the accessibility of 42 major European cities in relation to the road, rail, and air networks. They found, when analysing the improvements to the rail network through the introduction of the HST network proposed by the EC in 1990, that the HST significantly increased the average accessibility of the cities (measured in time units), but also significantly raised the inequality between the cities (a higher coefficient of variation in the level of accessibility between the cities). Following Bruinsma and Rietveld (ibid) analysis, Hall (1999) concludes that “without a connection to the European HST, any city’s accessibility within Europe could be seriously compromised...[and that] both the Shinkansen and the TGV seem to have favoured the large cities at the ends of the lines at the expense of smaller intermediate cities; cities that were bypassed did particularly badly” (ibid: 14)

The same notion is evident in Whitelegg and Holzapfel (1993) conclusion that “high speed rail developments pick out a few favoured areas or cities from a much larger number of

possibilities and confer on them additional advantages in terms of accessibility and the winning of inward investment...Nationally it leads to disinvestment in non-favoured areas and exacerbates long-standing historical problems of structural disadvantage and job loss” (ibid: 206)³⁷¹.

With further development of HST lines and as more time passes, there will be more evidence to underpin the different impacts associated with the introduction of new HST services. In the context of aircraft and HST substitution, the important aspect is the development of the HST network since this will determine the extent to which such substitution can take place. However, the expansion of the HST network depends on the impact it has in terms of time saving, improved accessibility, and wider economic and social impacts.

³⁷¹ Whitelegg and Holzapfel (1993) continue and explain that “this in turn produces a low level of efficiency in the use of expensive infrastructure. In the favoured areas it necessitates new investment where costs are already artificially raised by improved accessibility and attractiveness of the location.... For the non-favoured areas the consequences are just as bad, if not worse. Expensive infrastructure already in place is in danger of underutilisation and ultimately of disuse and closure, as lower levels of utilisation raise unit costs and force reductions in levels of service” (ibid: 206).

Appendix C: The main pollutants and gases associated with aircraft and HST operation impact on local air pollution

Carbon Monoxide (CO):

“Carbon monoxide (CO) is an odourless, colourless gas that is a by-product of the incomplete burning of fuels. CO reduces oxygen carrying capacity of blood and weakens the contractions of the heart, thus reducing the amount of blood pumped to various parts of the body and, therefore, the oxygen available to the muscles and various organs” (EPA, 1999b: A-3). This may lead to increased morbidity. CO is especially a problem in urban areas where synergistic effects with other pollutants mean it contributes to photochemical smog and surface Ozone (O₃). Some 90% of all CO emissions originate from the transport sector (Button 1993).

Hydrocarbon (HC) and Volatile Organic Compounds (VOC):

HC is an organic compound that contains the elements of carbon and hydrogen only. (TEST, 1991). They generally result from incomplete combustion of fossil fuel or from evaporation of fuel. Some VOCs have little or no known direct health effect, while other VOCs, for example Benzene, are known carcinogens. In addition, VOCs can cause a variety of environmental effects such as damage to plants, crops, buildings and materials. The principle environmental effect of VOCs is their contribution to the formation of Ozone and Particles (EPA, 1999b).

Nitrogen Oxides (NO_x):

Nitrogen and Oxygen can combine to produce a variety of compounds. The term NO_x is usually referred to nitrogen dioxide (NO₂) and nitric oxide (NO) which are the significant pollutants in this group. Nitrous oxide (N₂O) also belongs to this group but its environmental effect is mainly considered with climate change rather than air pollution. NO_x affect human mortality and morbidity through three separate channels: as NO₂ directly, as ammonium nitrate (a component of PM₁₀) and through a secondary reaction with VOCs resulting in the formation of Ozone (Maddison et al, 1996). NO_x affect lung function, and may harm immune system cells, increase susceptibility to infection and aggravate asthma (Whitelegg et al, 2001). NO_x also contributes to the formation of particles in the atmosphere. Even when it

does not form particles, NO_x itself is a brown gas that largely contributes to the visible smog effect evident in major metropolitan areas (EPA, 1999b).

Particulate Matter (PM₁₀):

Often referred to as small particulate matter, PM₁₀ are solid and liquid particles in the air of under 10-micron diameter. The term PM₁₀ comprises several types of particulate matter, the main two are those which are emitted directly to the atmosphere and those which are formed indirectly as secondary pollutants. Hence, emissions of SO₂ and NO₂ can both oxidise in the atmosphere to form ammonium sulphate and nitrate, and both are small particulate matter. Evidence exist that link PM₁₀ and premature mortality and morbidity (Maddison et al, 1996). Particulates are associated with a wide range of respiratory symptoms including coughs, colds, phlegm, sinusitis, shortness of breath and more (Whitelegg et al, 2001). In early research no attention was given to the size of the particles and they were usually referred to as aerosols. At present research often distinguishes between PM₁₀ and PM_{2.5}, the latter refers to particulate matter with a diameter of less than or equal to a nominal 2.5 micrometers (EPA, 1999b).

Sulphur Oxide (SO_x):

The main pollutant in this group is Sulphur Dioxide (SO₂) and the literature in many cases treats the two (SO_x and SO₂) as the same pollutant. SO₂ can affect human health through two main channels, directly as SO₂ concentrations and through its oxidation in the atmosphere to form small particulate matter. Emissions of this colourless, although strong smelling, gas can result in bronchitis and other diseases of the respiratory system. Coal fired electricity generation is a major source of this gas as well as diesel fuel (Button, 1993).

Appendix D: Noise standards and the measurement of noise

D1. Measuring noise

When measuring noise three factors are considered: intensity, frequency and time variation. The intensity of sound is usually expressed in decibels (dB). Frequency is defined as the rate of vibration of a sound source expressed in hertz (Hz), where a greater vibration indicates a greater frequency. Time variation of the sound level means that changes of sound level and frequencies over a short time tend to be disturbing to listeners (Janic, 1999).

The basic measurement of sound is in decibel (dB), which is a logarithmic quantity reflecting the nature of the human ear's response to sound pressure. As well as responding to sound in a logarithmic manner (meaning a 10% increase in decibel is more than 10% louder) the ear is also more sensitive at some frequencies than at others. The human ear responds very poorly at low frequencies (e.g. 10 Hz) and not particularly well at very high frequencies (e.g. 20 kHz) when compared with mid frequencies (e.g. 1kHz - 5kHz) (CfIT, 2001a). To account for this frequency sensitivity a frequency weighting is applied to measurements and calculations. The most common frequency weighting is the 'A-weighting'. A sound level to which A-weighting has been applied is presented in terms of dB(A).

A noise index that normalises the level of sound to a short period, 1 second, and thus allows measuring and comparing between short events of noise is the Sound Exposure Level (SEL). The SEL is "the level at the reception point which, if maintained constant for a period of 1 second, would cause the same A-weighted sound energy to be received as is actually received from a given noise event" (DoT, 1995: 5). In reference to measuring noise from transport operation, the SEL is used to measure the noise generated by one vehicle passing a reception point, be it a train or an aircraft.

To measure the noise generated from a number of vehicles passing by a reception point over a defined period of time the Equivalent Continuous Sound Level, usually marked L_{Aeq} , is used. " $L_{Aeq,T}$ is the level of a notional steady noise which, at a given position and over a defined period of time, T, has the same A-weighted acoustic energy as the actual fluctuating sound. $L_{Aeq,18h}$ is the Equivalent Steady Sound Level for the 18 hour period between 0600 hrs - midnight and $L_{Aeq,6h}$ is the Equivalent Steady Sound Level for the period midnight to 0600 hours" (ibid: 3). Another definition for L_{Aeq} is "the steady noise level over a defined period

that contains the same acoustic energy as the fluctuating level over that period” (CfIT, 2001: 29). The SEL index, described above, is the 'building block' of the L_{Aeq} measurement.

To take into account the different effect of the same noise at different periods of the day a factor of 5 dB(A) is usually added to the evening period (20:00-24:00) and a 10 dB(A) is added to the night period (24:00-08:00). Considering together the day, evening and night L_{Aeq} s result in a single time-weighted L_{Aeq} , the L_{den} that reflects the potentially greater annoyance from noise at different times of the day, and especially at night. This index “is currently considered to be the most appropriate general-purpose indicator of environmental noise exposure within the process of formulating the European Directive, and hence a suitable index for comparing different types of noise sources” (ibid: 30).

If a sound is not heard by anyone it can not be considered as noise. Therefore, measuring the noise/sound generated is not a sufficient indicator of noise pollution. What is needed is the number of people exposed to this noise (to how much or what level of noise each person is exposed to is considered within the units of noise by applying the A-weighting). This is done by measuring the noise at different distances from the noise source to determine the area exposed to the noise. Then, an estimate of the number of people within this area is made to arrive at the number of people exposed to noise. The effect of noise is usually represented on a map by drawing noise contour (a line on a map that connects location with the same level of noise) around the source of noise. The noise contours around London airports Heathrow, Gatwick and Stansted are presented at 3 dB(A) intervals starting at 57 dB(A). It is generally accepted that significant community disturbance starts at around this level of aircraft noise (DEFRA, 2001: 55).

To measure the monetary costs of noise the ‘hedonic price’ method is most commonly used. “Hedonic pricing is a technique that derives values for non-market goods such as environmental quality using information on the value of market goods such as residential property. By analyzing a large set of properties that are exposed to varying levels of noise annoyance, while controlling for other relevant characteristics, one can obtain an implicit price for the characteristic peace and quiet” (Schipper et al, 1998: 117).

Reviewing European literature, Navrud (2002) found that mainly two approaches are used to present the economic value of noise annoyance. In the first approach, the economic value per decibel per year is estimated in units of the Noise Depreciation Sensitivity Index (NDSI). The NDSI is defined as the average percentage change in property prices per decibel. In the second approach, the units used are economic value per year per person (or household) annoyed by noise. Two units are commonly used, independent of the level of annoyance:

value per person 'highly annoyed' and value per person 'annoyed'. Alternatively, values are also expressed as per person exposed to noise levels above a certain level e.g. 55 dB, without referring to any annoyance level, which means that persons who are exposed to noise, but are not annoyed by it, are also included. The second approach does not have to include an economic value, but can be used just to measure the number of people exposed to certain levels of noise (as noted above). This is, for example, the practice for measuring noise around airports in the UK (see DfT, 2003a).

D2. Noise standards

The recognition that noise has various negative effects led to the creation of noise standards by different bodies. In general, the EPA states that "sound above 65 dB(A) is considered annoying and sound above 125 dB(A) is painful. Noise generated from the transportation system generally falls above the annoyance level but below that which is painful" (EPA, 1999a: 32). The European Environment Agency determine that a limit of 55dB(A) is regarded as one which should not be exceeded to allow undisturbed sleep, while sound levels above 70 dB(A) make normal speech communication impossible (Whitelegg et al, 2001). Other bodies, cited by the DEFRA (2001), also set desired level of ambient noise. Examples are given below.

The European Commission's fifth action program on the environment specifically addressed the issue of night noise exposure at home. It proposes the following for night-time noise:

- To phase out average exposure above 65 dB(A) Leq.
- To ensure that at no point in time a level of 85 dB(A) Leq is exceeded.
- To aim to ensure that the proportions of the population exposed to average levels between 55 and 65 dB(A) Leq should not increase.
- And, that exposures in quiet areas should not increase beyond 55 dB(A) Leq.

The Organisation for Economic Co-operation and Developments (OECD) identified a threshold for noise nuisance in terms of day-time L_{Aeq} as follows:

- At 55-60 dB(A) noise creates annoyance.
- At 60-65 dB(A) annoyance increases considerably.
- And, above 65 dB(A) constrained behaviour patterns, symptomatic of serious damage caused by noise arise.

The Royal Commission on Environmental Pollution 18th report from 1994 proposed to reduce transport noise as follows:

- Day-time exposure from road and rail noise to not more than 65 dB, $L_{Aeq,16h}$ at the external walls of housing.
- Night-time exposure from road and rail noise to not more than 59 dB, $L_{Aeq,8h}$ at the external walls of housing.

The World Health Organisation recommends maximum noise level at different location and time which are shown in table D1.

Table D1: World Health Organisation recommended maximum noise level

Image removed due to third party copyright

Source: Whitelegg et al (2001).

The above standards, defined by different bodies, provide an indication of the desired levels of noise. It is not likely that they will be achieved in the near future for all people. For example in 1989, 562,100 people around Heathrow airport were exposed to a noise level of 57 L_{eq} and over, and 147,500 and 36,800 people were exposed to noise levels of 63 L_{eq} and 69 L_{eq} respectively. Although these numbers were reduced by 1999 to 155,600, 53,900 and 21,900 for the 57, 63 and 69 L_{eq} noise contour respectively (DEFRA, 2001) it shows that many people were exposed to noise levels above the recommended limits.

Appendix E: Calculation of airport and ATC charges

Airport landing charges cover in effect also the take-off, and might be termed turnaround charges since they cover a 'visit' of an aircraft to an airport. Parking charge is levied on the time the aircraft spends at the gate between flights, the turnaround time. There are also charges for longer stay, e.g. overnight, or a different charge when the aircraft is parked on the apron and not at the gate. However, these cases were not considered in the research. "The turnaround time for a short haul flight is defined as the time for an aircraft to complete full off-loading, loading and where required, catering and cabin cleaning procedures" (Cheng-Lung and Caves, 2000: 201).

To take account of the different charges at Heathrow and CDG, the charges were calculated for both airports, divided by two and then summed to arrive at the charges on the route. For the calculation of parking charge it was assumed that the aircraft turnaround time is 45 minutes. The basis for this assumption was as follows. Short-haul scheduled carriers are usually constrained to operating between 07:00 and 22:00 (Williams, 2001), and during summer 2003 BA's first flight from Heathrow to CDG departed at 6:20 and the last flight left Heathrow at 19:45 (BAA, 2003a). Considering that BA's B737-300 flew, on average in 2001, 8h41m block hours per day (IATA, 2001), and that a flight from Heathrow to CDG takes 70 minutes it translates to about 8 flights per day, and about 45 minutes turnaround time between flights. The parking charges were calculated, based on 2002 rates, for each airport, divided by two and then summed.

The two charges for ATC services imposed on each flight are: En-route charge, which is paid for flying in the upper air-space and Air Navigation charge, which is for ATC services from the point the aircraft leaves the airport until it reaches the upper air-space, or vice versa. Each country's civil aviation authority determines the charges for aircraft using its airspace based on a fixed formula. For the En-route charge the distance flown in each country's air space is considered, and this was assumed to be equally divided between France and the UK for a Heathrow to CDG flight. For the Air Navigation charge only the French charge was available and was used. The different formulas used to calculate the charges are presented below.

At London Heathrow airport (BAA, 2001):

Landing charge: For Chapter 3 base aircraft*: £335 during off peak.

Peak/night time: £465**

* Base charges apply to jet aircraft meeting the requirements of ICAO Annex 16 Chapter 3.

** Peak period: 0700-0959 UTC (GMT) and 1700-1859 UTC (GMT), 1 April to 31 October.

Parking charge: Charge of quarter hour or part thereof: £3.40 plus 5.6p per metric ton (based on the Maximum Take off Weight (MTOW)).

Peak parking element: occupation of a pier-served stand in the Passenger Terminal Area between 0700 and 1229 UTC (GMT), 1 April to 31 October – each minute will count as 3 minutes.

At CDG airport (ICAO, 1998; Aujouannet, 2002):

Landing charge: For aircraft with MTOW of over 51 ton:

Charge (€) = 180.78 + 8.24(ton – 50)

For aircraft in noise group 4 (factor 1). The B737-300 is categorized as group 5 (factor 0.85-0.90 depending on time of day).

Parking charge: For “Ramp” parking aircraft “in contact”.

Fixed part: €1.77 per ton

Variable part: €0.16 per ton per hour

Aeronautical charges (Eurocontrol, undated; Aujouannet, 2002):

En route charge: $R = T \times D \times \sqrt{(\text{weight} / 50)}$

R = Charge. T = Unit rate: €52.42 for French air space and €89.92 for UK airspace. D =

Great circle distance expressed in hundreds of kilometres taken to two decimal places.

Weight: MTOW.

Terminal Navigation Charges: applied to each take-off.

Charge = K x Tu x Cp

K = Correction factor 1.247

Tu = Unit rate €4.11 for France

Cp = Service unit = MTOW to the power of 0.9