The University of Manchester

EPSRC
Engineering and Physical Sciences Research Council

Airports Environmental Investment Toolkit

Paul W Chan and Vivian Liang
School of Mechanical, Aerospace and Civil Engineering
paul.chan@manchester.ac.uk
+44 0 161 275 4319 or +44 0 774 783 5506

Combining the strengths of UMIST and The Victoria University of Manchester

University of Cambridge · UCL · Cranfield University

AETN Meeting, Lincoln
8 September 2011

MANCHESTER
1824

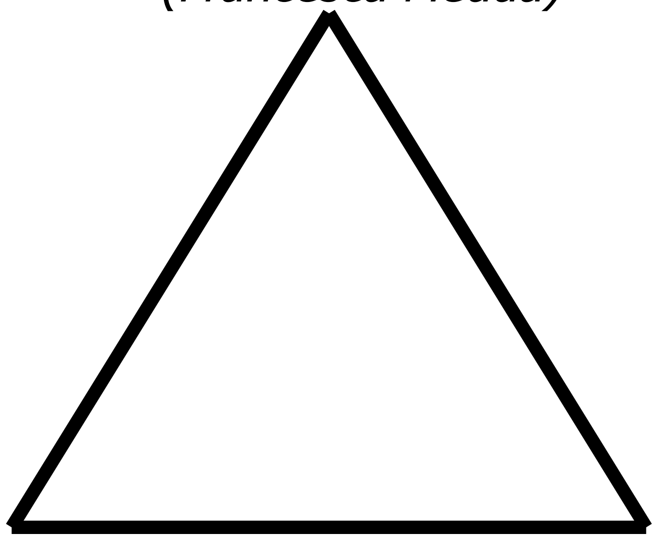
The University of Manchester

Trade-offs and the Triple Bottom Line in Aviation

Economic

UCL: Financial modelling

(Francesca Medda)



Social

Manchester: Decision-making

Environmental

Cambridge: Aviation technologies

(Adam Boies)

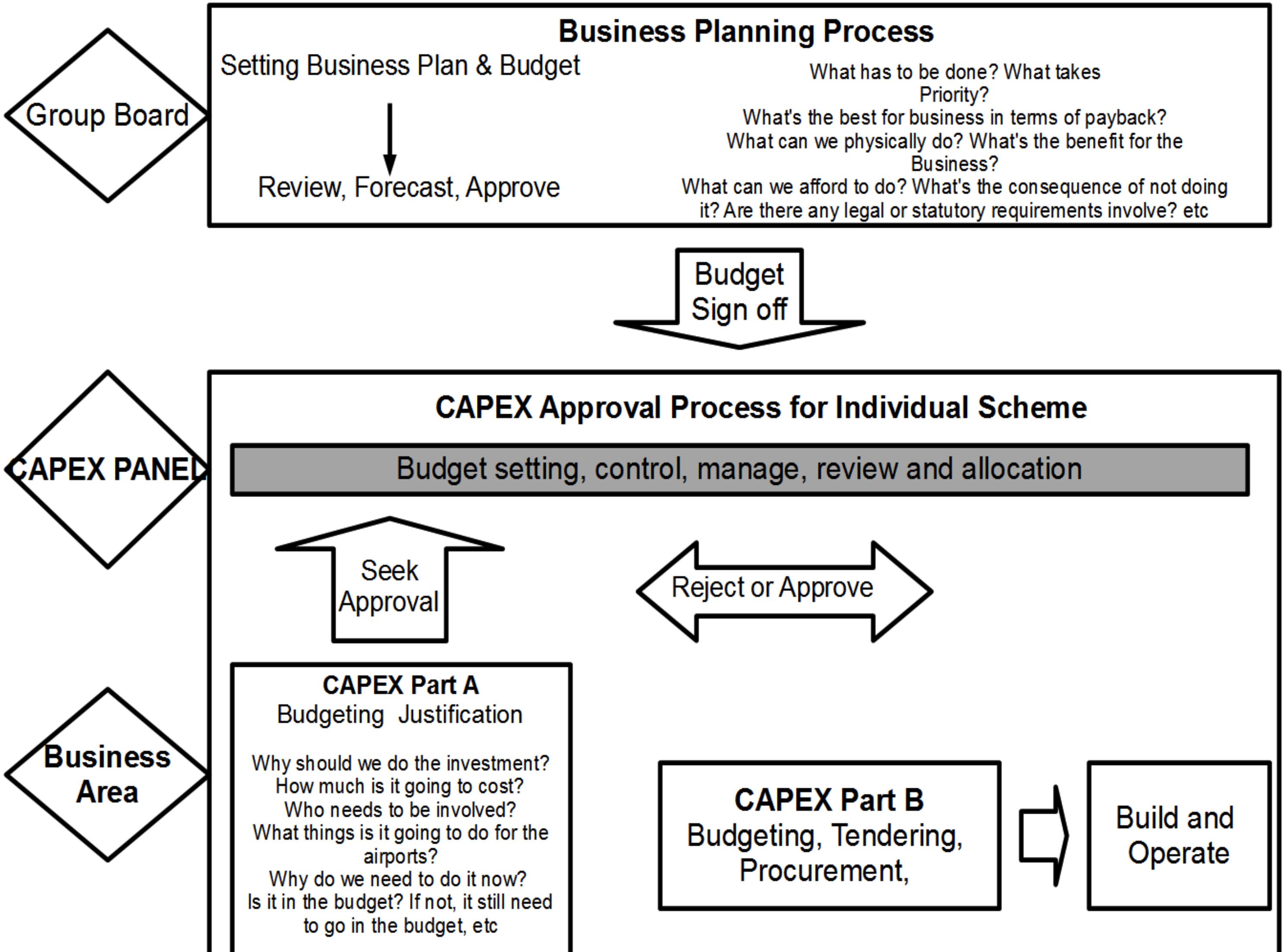
Manchester Work Package

- Key financial processes at Manchester Airport:
  - ***Macro process***: organisational business planning cycle including signing off operational costs/ expenditure, financial forecasting etc.
  - ***Micro process***: Capital Expenditure Investment Application Process (CAPEX) – notional budget of what the company is thinking of spending, and each project then requires individual approval process

MANCHESTER 1824

The University of Manchester

How the Macro and Micro Connect?



Categorisation of Investments

Investment Category	Rationale	MA CAPEX Plan Examples
Regulatory & Renewals	Spending that need to be made in order to comply with the regulatory requirements, this includes meeting environmental, security and health and safety obligation. Also, replacement for any equipment, machinery or areas of the airport that required being repair or renewing.	CAA, DfT requirements: Security Improvement, Body Scanners, Hold Baggage Screening Replacement. Energy Efficiency Scheme, Runway Relighting & Resurfacing, Terminal Boiler Replacement, Noise Monitoring.
Cost Reduction	To reduce going costs and increase efficiency. This often is the investment on technology.	Automatic Boarding Card Readers, Hand Dryer Replacement.
Yield Enhancement	To increase the income of the business, without requiring increases of passenger numbers. Examples of this type of investment are the retailer and car parking schemes that generates further incomes for the airport.	Car Park Developments, Retail Upgrades, Concorde and Aviation Viewing Park scheme, Terminal 1 Escape Lounge.
Capacity Enhancement	Building development of the airport, as in creating capacity to accommodate more number of passengers, such as building more check in desks in terminal and baggage capacity improvement.	New Car Parks Spaces at Terminals 2 & 3, Terminal 1 Airside Smoking Area, Terminal 1 Ground Level Check in Refurbishment.

Two Critical Stories

Environmental manager and new runway

Purchase of recycling bins

Critical Questions

- How do we and the practitioners know what the 'value' of socially and environmentally responsible activities?
- How do we know future worth of what we do now?
- What happens when there are 'competing' values? Are 'competing' values necessarily bad?
- How do practitioners circumvent formal processes to push through socially and environmentally responsible actions?

UCL Work Package

- Two broad streams:
  - ***Asset returns***: How do we get stable long-term returns, foreseeable cash flow and relative protection from crises? (Maximilian Vermorken)
  - ***Financial returns***: What are the returns on the voluntary activities undertaken under the umbrella of corporate social responsibility (CSR)? (Eleni Rapti)

Approach to Develop a Model for Asset Returns

Phase A

Understanding Non-Gaussian behaviour of asset returns: challenging conventional financial theory for optimal asset allocation, optimal risk diversification

Understanding the listed infrastructure market: Macroeconomic and sectoral dependencies, market structure, actors, assets

Phase B

Mapping risks in airport investment

Phase C

Mapping benefits of diversification in Airport Investment

Phase D

Quantifying risk premia, and recession robustness of airport investment

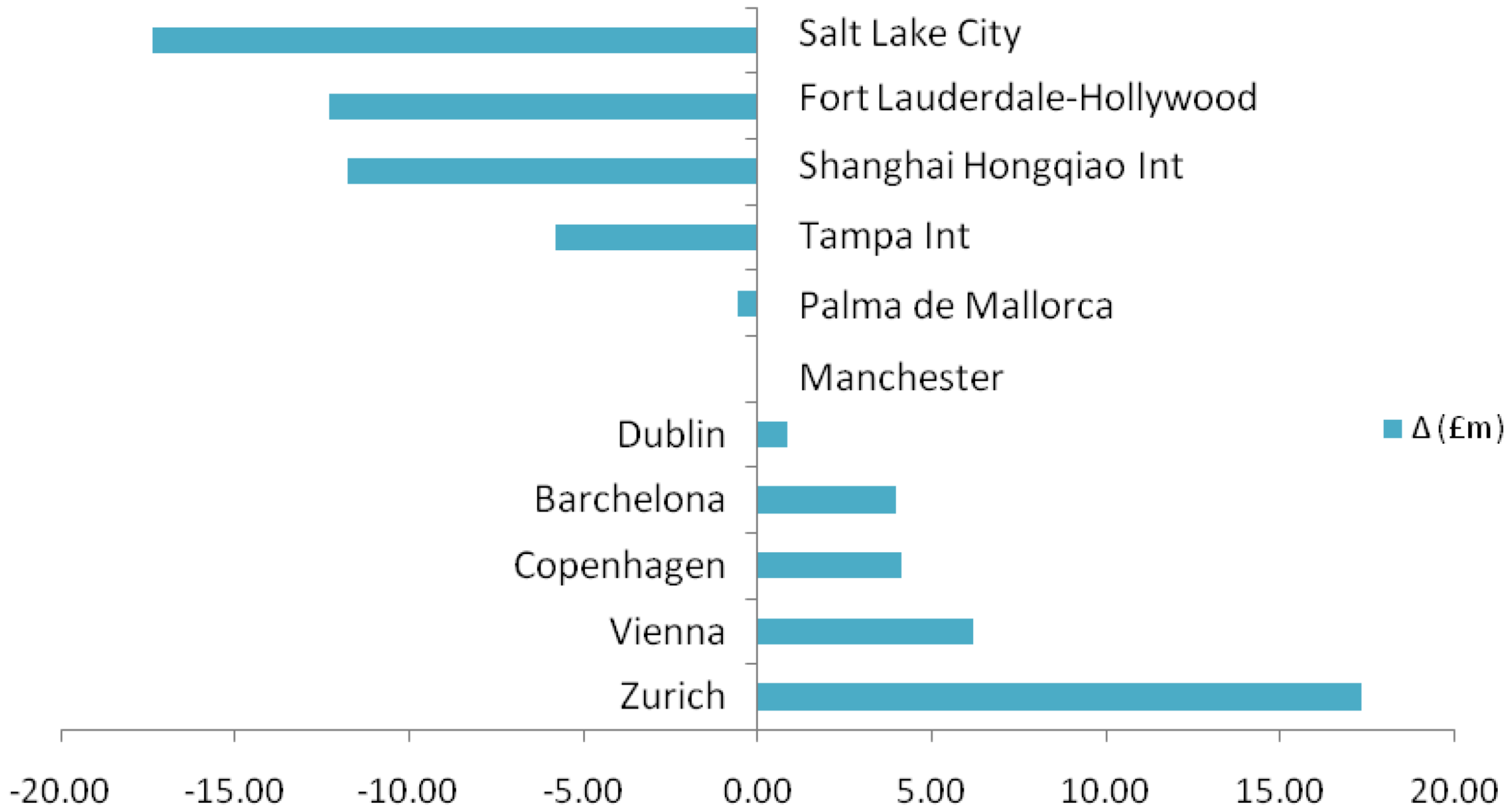
Result

Redefining optimal asset allocation for Infrastructure Funds

Evaluating Airport Financial Returns

- Valuation multiples: firms of the same industry with similar operating and financial characteristics are compared.
- Basic assumptions: CSR activities intervene in the assets of a company
- Data: net assets (NA); the book value (BV) and airport earnings (EBITDA)
- We used Manchester Airport as a reference point:
  - Airport characteristics (e.g. number of terminals, runway length, proximity to CBD)
  - Inputs: domestic/international routes; number of employees
  - Outputs: number of passengers; number of flights per day

Airport Financial Returns: Some Early Findings



Differences in million (£s) between Manchester and Peer Set due to CSR activities, after quantifying the NA/EBITDA ratio.

The University of Manchester

Cambridge Work Package

Atmospheric Environment 45 (2011) 5415–5424

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Air quality and public health impacts of UK airports. Part I: Emissions

M.E.J. Stettler[a,b], S. Eastham[a], S.R.H. Barrett[b,*]

[a] Department of Engineering, University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, United Kingdom
[b] Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA

ARTICLE INFO

Article history:
Received 3 March 2011
Received in revised form
4 July 2011
Accepted 5 July 2011

Keywords:
Aviation
Airport
Emissions
Air quality
Particulate matter

ABSTRACT

The potential adverse human health and climate impacts of emissions from UK airports have become a significant political issue, yet the emissions, air quality impacts and health impacts attributable to UK airports remain largely unstudied. We produce an inventory of UK airport emissions – including aircraft landing and takeoff (LTO) operations and airside support equipment – with uncertainties quantified. The airports studied account for more than 95% of UK air passengers in 2005. We estimate that in 2005, UK airports emitted 10.2 Gg [–23 to +29%] of NO_x, 0.73 Gg [–29 to +32%] of SO_2, 11.7 Gg [–42 to +77%] of CO, 1.8 Gg [–59 to +155%] of HC, 2.4 Tg [–13 to +12%] of CO_2, and 0.31 Gg [–36 to +45%] of $PM_{2.5}$. This translates to 2.5 Tg [–12 to +12%] CO_2-eq using Global Warming Potentials for a 100-year time horizon. Uncertainty estimates were based on analysis of data from aircraft emissions measurement campaigns and analyses of aircraft operations.

The First-Order Approximation (FOA3) – currently the standard approach used to estimate particulate matter emissions from aircraft – is compared to measurements and it is shown that there are discrepancies greater than an order of magnitude for 40% of cases for both organic carbon and black carbon emissions indices. Modified methods to approximate organic carbon emissions, arising from incomplete combustion and lubrication oil, and black carbon are proposed. These alterations lead to factor 8 and a 44% increase in the annual emissions estimates of black and organic carbon particulate matter, respectively, leading to a factor 3.4 increase in total $PM_{2.5}$ emissions compared to the current FOA3 methodology. Our estimates of emissions are used in Part II to quantify the air quality and health impacts of UK airports, to assess mitigation options, and to estimate the impacts of a potential London airport expansion.

1. Introduction

1.1. Context

Aviation affects the environment via the emission of pollutants from aircraft and supporting airport infrastructure, impacting on human health and well-being, and on the climate (Lee et al., 2010). Between 1960 and 2005 worldwide scheduled passenger air travel grew from 109 billion to 3.7 trillion passenger-km travelled. This represents an average growth rate of over 8% per year (IPCC, 1999; ICAO, 2006), while over the next two decades global air travel is forecast to grow by 4.5–6% per year (Lee et al., 2009).

In the UK, a significant political issue has been the proposed expansion of London Heathrow Airport, and potentially other London airports. Heathrow expansion was the policy of the previous administration, although the London Assembly (2010) criticised the plans on air quality grounds and the current administration does not plan to increase capacity at Heathrow or Stansted airports (HM Government, 2010). However, the debate on air quality impacts of potential expansion has occurred without quantification of those impacts on human health on a regional scale.

Emitted pollutants resulting from aviation include greenhouse gases (GHGs) and particulate matter that contribute to forcing of the climate (Lee et al., 2010) and gases and particulate matter that are harmful to human health (Barrett et al., 2010). Aircraft engine emissions include CO, CO_2, H_2O, SO_2, NO_x ($NO + NO_2$), a range of hydrocarbons (HC), and volatile (sulphate and organic carbon) and non-volatile (mostly soot) particulate matter (PM). Emitted PM has an aerodynamic diameter much less than 2.5 μm ($PM_{2.5}$), with modal diameter less than 100 nm (Onasch et al., 2009; Petzold et al., 2005). Non-volatile PM exists at the engine exit plane while volatile PM nucleates as new particles or condenses on existing particles in the cooling exhaust plume (Wayson et al., 2009; Onasch et al., 2009; Petzold et al., 2005). $PM_{2.5}$ is thought to have adverse health impacts at concentrations down to pre-industrial levels and there is epidemiological evidence to show that adverse effects are associated with both short and long term exposure (WHO, 2006).

* Corresponding author.
E-mail address: sbarrett@mit.edu (S.R.H. Barrett).

1352-2310/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.atmosenv.2011.07.012

- Initial work done to develop a model of emissions, air quality and health impacts:
  - Methodology for calculating gaseous and particulate matter emissions of air quality (integrating airside equipment and aircraft in LTO cycle)
  - Uncertainties estimated using a Monte Carlo approach, considering operational and scientific factors, including:
    - Schedules, times-in-mode
    - Thrust settings and fuel flow
    - Emissions including SO_x, HC, CO, CO_2, NO_x, PM, APU

Cambridge Work Package *(Future Work)*

- Development of Emissions Inventory Tool (contact Marc Stettler on ms828@cam.ac.uk for access to this tool)
- Develop method for estimating particulate matter as current standard is under-estimating emissions (identify deficiencies with current regulated method of estimation)
- Uncertainty assessment of landing and take-off emissions in collaboration with Steven Barrett in MIT
- Relate UK airport emissions to public health impacts and identify mitigation options (e.g. single engine taxi, ultra-low sulphur fuel, electrification of airside support equipment and restriction of APUs) – what can airport operators really do?

Progress to Date and Work Ahead

- Understanding the field:
  - How do airport operators currently make decisions? What are the current criteria used and why? (Manchester)
  - What are the current investment returns for what airport operators do? (UCL)
  - What are the current emissions from airports and what are the likely consequences? (Cambridge)
- Challenging the field:
  - What is a better process and how can we improve the criteria? (Manchester)
  - What is a better investment model? (UCL)
  - What can we do about the emissions to limit the consequences? (Cambridge)

Progress to Date and Work Ahead

- Understanding the field:
  - How do airport operators currently make decisions? What are the current criteria used and why? (Manchester)
  - What are the current investment returns for what airport operators do? (UCL)
  - What are the current emissions from airports and what are the likely consequences? (Cambridge)
- Challenging the field:
  - What is a better process and how can we improve the criteria? (Manchester)
  - What is a better investment model? (UCL)
  - What can we do about the emissions to limit the consequences? (Cambridge)

MANCHESTER
1824

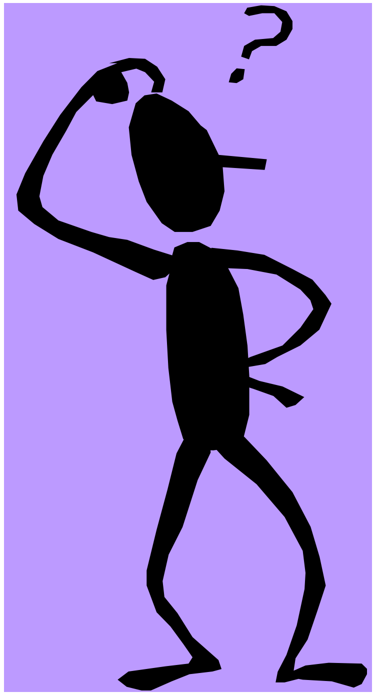
The University
of Manchester

Trans-disciplinary Challenges

- How do we resolve different units and levels of analysis?
  - Reconciling between macro-level and micro-level analysis, and;
  - Interrogating the assumptions made by academic and industrial partners.
- Where is the data?
  - Meaningfully sharing data, and;
  - Finding, consolidating and translating data from the airport to fit what the academic wishes to model.

The University of Manchester

MANCHESTER 1824



Q and A