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Green Airport Design Evaluation (GrADE) – methods and tools improving infrastructure planning

Paolina Ferrulli [a,*]

[a]*Università degli Studi di Firenze, via di San Niccolò 93, Firenze 50125, Italy*

Abstract

Aviation plays a significant role in modern socio-economies, providing connectivity and accessibility, and facilitating commerce. Airports are critical nodes in the air transport system and of the territory connectivity as well. Along with the growth of airport infrastructures, airport-related business, commercial, residential and spatial development takes place in the airport surroundings connected by surface transport infrastructure. Airports no longer simply comprise aviation related functionalities (e.g. passenger, cargo, and aircraft handling facilities), they have evolved to include shopping and hotel complexes, conference facilities, as well as industrial zones, logistic centres and inter-modal public transport hubs. Concepts such as “aerotropolis”, “airport city”, “airport corridor”, “airport region”, and so on, have emerged to denote even more the dramatic structural and operational evolution on the airport site and in the immediate surroundings. These developments have spatial implications on various levels and scales.
Europe faces a particular challenge in respect of its airport infrastructure network because of limited capacity that prevents aviation responding to demand when it arises and the difficulty of securing planning approval for airport infrastructure development. This is due to the dense urbanisation of the continent, the complex system of rules and planning regulations that have arisen as a result and opposition from local residents and their politicians to airport growth. The ability to deliver further airport growth and development into infrastructure design integrated with the urban planning will therefore be a major sustainability challenge for the future. A strategic and integrated approach to define the airport infrastructure design complying with the specific sustainability requirements is needed. The aim of the paper is to illustrate the results of a doctoral research focused on the development of a framework for the sustainability performance-based evaluation of airport project design and technological strategies to enhance the environmental capacity of the infrastructure during its life cycle.

* Corresponding author. Tel.: +39-3296929080.
E-mail address: paolina.ferrulli@unifi.it

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Environmental and operational capacity can be maximised through a long-term planning ensuring an effective environmental management that compensates for growth through the introduction of eco-efficient infrastructure, technological, and operating strategies. The proposed research defines specific methods and tools enabling both design project control and sustainability appraisal. The methodological approach follows a systematic process analysis, linked to modelling studies and the development of sustainability indicators that inform a site wide approach to the design of airport infrastructure.
The objectives is achieved through the definition, analysis and assessment of the solutions for environmental capacity and sustainable airport-network development through in-depth study of the impacts arising from airport operations and infrastructure. The project aims at developing a framework for governance to manage and enhance the investments for the infrastructure development by cross-evaluating all the aspects affecting the project design decision process.
The Green Airport Design Evaluation (GrADE) method and its respective tools will contribute in achieving the goal of sustainable development of airport infrastructure providing a methodological framework to measure and monitor environmental performance and creating new opportunities for the aviation regulatory organisations and airport owners to define business model and strategies to enhance sustainable airport infrastructure design within the regional transport network.

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Keywords: airport design; decision support tool; life cycle assessment; integrated project delivery; performance based building design; experience design; airport city; airport region; sustainable mobility

1. Commercial air transport growth and trends

Since the advent of commercial air transport, the aviation sector has shown a steady growth all over the world. The oil crises in the Seventies, the Gulf War in 1991, the terrorist attack on the World Trade Center in 2001, the SARS epidemic of 2003 and financial crises such as that of 1998 and the most recent in 2008, have had an impact on the aviation industry. But even events that have shaken society and had a significant impact on the worldwide economy, caused the contraction in the volume of air traffic that lasted only for a few months and never more than three years (Airbus 2010). This sector has shown that, although significantly exposed to the effects of external factors, it can also rapidly absorb such shocks as recorded in 2004 with a growth of 14% and in 2010 with a growth of 7% (Airbus, 2013). As a result, at a global level, aviation has demonstrated a sustained and steady increase in air traffic linked to demographic and economic development, especially in emerging economies countries.

The rise of cities, which are the main engine of economic growth and globalization will lead to a rapid transformation of international trade, tourism and attracting multinational companies in Asia, Russia, Latin America and Middle East. Megacities such as Shanghai, Beijing, Seoul, Mumbai, Delhi, Dubai will need effective and fast connections not only with the other countries of the world, but also within their own national territory. Where the road and rail network is insufficient or difficult to be increased and the distances between cities are more than 1000 km (620 ml), air transport will be the most efficient infrastructure.

As a result, at a global level, aviation has demonstrated a sustained and steady increase in air traffic linked to demographic and economic development, especially in emerging economies. Urbanisation and the rise of cities, are major engines of economic growth and globalization that lead to a rapid transformation of international trade and tourism, attracting multinational companies, as is currently being witnessed in Asia, Russia, Latin America and Middle East. Megacities such as Shanghai, Beijing, Seoul, Mumbai, Delhi, Dubai will need effective and fast connections not only with other countries of the world, but also within their own national territory.

European Commission's forecasts indicate that in the immediate future, the highest airport passenger growth will be concentrated in the Middle East, with an average growth rate of 10.8% p.a., followed by Latin America (8.0%), Asia and Pacific region (6.8%) and Africa (6.0%), (2013). These trends also show that the developing countries will have an highest rates of growth in passenger traffic compared to the "mature economies" of Europe and North America. The data also indicate that the aviation market will shift its focus to Asia, the Middle East and Latin America where massive airport construction can be anticipated over the coming decades. This phenomenon is already being demonstrated in China where 70 airports are currently under development or reconstruct, some of which are being developed to handle as many as 100 million passengers per annum. The increase rate of traffic and urbanisation is associated with a massive development of airport infrastructure. These factors are reflected in the territory served by the creation of new megacities major hub airports.

1.1. Europe's air transport network challenges

Airports are critical nodes in the transport system and can have a vital role in supporting the socio-economic development of city regions. The structure and organisation of the transport systems have determined the evolution and changes of human settlements in each age, influencing the creation of public spaces designed to accommodate nodes and connections (Button et al., 1995; Trinder, 2001; Woudsma & Jensen, 2003). Airports have the ability to re-model the location of economic activities and urban development (Department for Transport (DfT), 2004; Knippenberger & Wall, 2010; Blonigen & Cristea, 2012). Therefore strategies for the development of air transport must be considered a priority, integrating them in the context of broader strategies for economic development and the infrastructure of the country.

The 170 000 links in the network of European air traffic, are supported by an infrastructure made up of 2 000 airports. Therefore, understanding the variety of airports in Europe, their distribution, their traffic patterns, the mix of aircraft, their strengths and weaknesses, is essential to understand the strengths of the network of air traffic as a whole (Eurocontrol, 2007) and the implications of growth in other parts of the world for aviation infrastructure development. Europe faces a particular challenge in respect of its airport infrastructure because of limited capacity that prevents aviation responding to demand when and where it arises (Advisory Council for Aviation Research in Europe (ACARE), 2008) and the difficulty of securing planning approval for new airport infrastructure development due to the different challenges they have to comply with in the short, medium and long-term period (ACARE, 2012). This is mainly due to the dense urbanisation of the continent and the complex system of rules and planning regulations that have arisen as a result and opposition from local residents and their politicians to airport growth. The future of air traffic growth will be limited by the capacity of European airports: by 2030, if current trends will be proved, 19 major European airports, including Paris Charles de Gaulle, Warsaw, Athens, Vienna and Barcelona will overreach their maximum capacity. The congestion that would result could cause delays for 50% of all passenger and freight. Currently already seven European airports are among the 30 most congested in the world: London Heathrow, Paris Charles de Gaulle, Frankfurt, Amsterdam Schiphol, Madrid Barajas, Monaco, Rome – Fiumicino (Eurocontrol, 2013; European Commission, 2013).

To respond to the increasing levels of congestion, European countries adopt traffic management policies that make it more efficient flight operations. The high levels of congestion and delays at airports during the hours of takeoff and departure of aircraft produce an increasing pressure both on the quality and capacity of air service and on the environment through the introduction of an increasing amount of pollutants. Increasingly it is not the availability of land or finance that constrains airport development, but rather the environmental consequences of the construction itself or the resultant aviation growth that would arise from it. This has given rise to the concept of airport environmental capacity (Coleman, 1999; Upham et al., 2003; Thomas, 2013). It is evident that the debate on the subject is not only focused on the noise and air quality impacts on the areas surrounding the airport, but has expanded the focus on the effect that airport and aviation activities have on climate change through carbon emissions, the use of resources (energy, water), the pollution of water and air, the management of wastes (European Environment Agency (EEA), 2007, 2012; Thomas et al., 2010; National Air Traffic Services (NATS), 2011; Department for Environment, Food and Rural Affairs (DEFRA), 2012; Eurocontrol, 2013).

2. Airport sustainable development

The Airport Council International (ACI) defines airport sustainability as a 'holistic approach to managing an airport so as to ensure the integrity of the economic viability, operational efficiency, natural resource conservation, and social responsibility of the airport' (www.aci-na.org). The design of the airport – as infrastructure consisting of multiple functional spaces and facilities and integrated with the surrounding territory – requires many levels of analysis and assessment to evaluate the development constraints and the impacts on the environment at different scales, in function of traffic capacity.

2.1. Airport environmental capacity

A wide range of impacts on local communities and the natural environment can constrain the operation of airports and restrict their ability to secure planning approval for future growth (Upham et al., 2003; Thomas et al.,

2004). Airport infrastructure growth depends on the assessment of those issues and the opportunity to strategically and systematically manage them during the design process. Even though the operational capacity strictly depends on infrastructure factors – such as requisite airspace, number of runways, extent of taxiway and apron development, number and size of terminals and landside facilities and the ease of access – a number of environmental constraints may prevent their potential traffic growth and future development (Thomas et al., 2010; Thomas & Hooper, 2011; Thomas, 2013). Environmental impacts are associated with the operations of the airport and the specific conditions and characteristics that pertain the area in which the airport is located – proximity to the houses, other polluting sources and industries, water supplies, energy resources and materials availability, climate changing conditions, sensitive habitats and others. They are even more critical when additional airport infrastructure has to be provided in order to maintain the operational efficiency related to the increasing air traffic demand (Thomas *et al.*, 2004).

Today, environmental constraints affect 70% European airports (Eurocontrol, 2013) and these constraints can be predicted to grow, as they are related to the pressure of traffic growth, competition for resources with other sectors, increasing democratisation and changing public attitudes, consequences of climate change. Adverse environmental and community impacts can result in failure of legislative compliance and planning approval for new infrastructure development. The commercial industry, or indeed governmental concept of sustainable development – defined as the ability of the airport to continue to grow (Thomas, 2013) – imply consider that the environmental issues could potentially constrain operations of future growth when:

- The implications of climate change affects infrastructure operating capacity or planning decisions;
- General operations, noise, emissions, third party exceed:
  - regulatory limits (risk limits, proximity to built up areas) or planning agreements (causing failure of planning approval),
  - tolerance within surrounding communities (arising from namely fear of air accident, high levels of noise, local air quality);
- The airport cannot secure resources (e.g. land, energy, water) to allow normal operations and growth;
- Further infrastructure growth is restricted by sensitive habitats, sites or buildings (houses).

The European Commission explicitly notes that ‘the development of transport systems must not be at the expense of the quality of life of citizens or the destruction of the environment. The indefinite continuation of current trends in transport in certain modes (road, air) would be unsustainable in relation to its environmental impact, in particular as regard climate change’ (European Commission, 1998). This single definition of sustainable development needs to be implemented on the basis of specific social and economic conditions related to the different situations (e.g. regional and local policies, urban configuration, *etc.*). As a result, even if there is a general definition of this concept, this must be “translated” and adapted for every single piece of infrastructure, evaluating the magnitude of social, economic and environmental concerns, in order to define the specific conditions that impact upon sustainable development. Defining and indicating sustainability will always depend on the definition of all these interrelated aspects.

2.2. Airport infrastructure constraints to growth

The European Commission communication COM (2011) 823 EU “Airport policy in the European Union – addressing capacity and quality to promote growth, connectivity and sustainable mobility”, confronts this problem by proposing a European regulation scheme that could address three challenges, namely capacity, service quality and environment, through improving technologies, efficient operations and infrastructure design. Sustainable development at an airport concerns developing an infrastructure that facilitates the long term growth of the site so that the airport can continue to respond to demand when it arises. The conventional capacity of an airport is considered in terms of its infrastructure capacity (runways, taxiways, terminal, etc.) and how well that is managed. It is becoming increasingly clear however, that the operational capacity of an airport and its ability to grow (i.e. obtain planning approval for growth) is increasingly linked to the environmental impacts of its operations.

Airport performance objectives, level of performance targets and plans to achieve the targets are no longer limited to the problems of air traffic, but also cover the ground infrastructure and the airport layout plan. The design of the airport, as infrastructure consisting of multiple functional space and facilities and integrated with the surrounding territory (accessibility, business investment, social return, *etc.*) seeks many levels of analysis and

assessment to evaluate the development constraints and the impacts on the environment at different scales. Working in this way means that long-term planning of airport areas has to take into account environmental constraints and the relationship with the urban functions set up in proximity of airport areas. By combining the advanced and innovative knowledge in the technology sector to a systematic system of regulations and standards, it will be possible to plan and manage the development of an ever-changing industry such as aviation, linked to the variability of the global economy, the continuous updating of the technologies, the constant growth in traffic demand and the environmental constraints related to the airport operation and design but also affected by the changing climate.

The environmental impacts, resulting from the rapid and ongoing growth of the industry, are increasingly restricting current operations and the potential for future growth. This scenario has given rise to the concept of environmental capacity at airports which demands long-term planning, ensuring effective environmental management that compensates for growth through the introduction of eco-efficient infrastructure, technologies, operating systems and even new business models (Thomas et al., 2001; Upham et al., 2003). Architects have played a significant role, historically, in the development and design of airports that meet the essential requirements of the air transport industry (e.g. operational efficiency, capacity, costs, safety). However increasingly there are having to focus on environmental issues related to terminal design. It is becoming apparent however that future sustainable development of airport will require that a much wider variety of environmental issues will have to be addressed not at the level of an individual building but site-wide.

3. Developing Green Airport Design Evaluation (GrADE)'s method and tools

The development of sustainable airport infrastructure depends on achieving correct balance between social and economic objectives within the limits imposed by the environment (Upham et al., 2003). The integration of these concepts implies the definition of what are the environmental constraints to airport development and how this is affected by the design of infrastructure and its configuration, and technological, operational and business features.

The research investigation focused on the issues concerning the design management and the way in which the design process affects airport quality on the environmental, typological and technological sides. The research on the design science and building sustainability evaluation has a direct impact on the users, the environment, the community and the operation and management of the airport. It can be achieved by paying more attention to aspects of design management and project information integration. This issue falls within the scope of the Framework Horizon 2020[1] initiative, which has as main objective to bridge the gap between research, various industrial sectors and the market supporting the development of technologies and processes that have resulted in products of commercial interest toward sustainability.

3.1. Green building assessment models

The variety of processes to be integrated during the design process development requires methods and tools of government that enable the management of the sets of variables characterising the complexity of building. Information management associated with parametric systems concerning the performance for sustainability plays a key role in terms of innovation helping to anticipate the decisions that affect the performance levels of the final product, since the preliminary stages of the process. Therefore the evaluation of environmental issues and the selection of design and technological strategies for minimising those impacts represents a priority in the early stages of planning and design of new infrastructure or of the expansion of the existing ones.

In pursuing sustainability in the Architecture, Engineering and Construction (AEC) industry, governments are developing and adopting green building standards and regulations and providing incentives (e.g. permissions and financial support) to ease sustainable development (Robichaud & Anantatmula, 2011). Environmental sustainability assessment has primarily evolved in connection to the Environmental Impact Assessment (EIA) and the Strategic

[1] Horizon 2020 is the financial instrument implementing the Innovation Union, a Europe 2020's flagship initiative aimed at securing Europe's global competitiveness. Seen as a means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament. They agreed that research is an investment in our future and so put it at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs (www.ec.europa.eu).

Environmental Assessment (SEA), (Sheate *et al*., 2003). EIA has demonstrated its limited capacity in evaluating alternatives as it is related to the late stage of decision-making process (Steinemann, 2001). The Directive 2001/42/EC of the European Parliament on the assessment of the effects of certain plans and programmes on the environment and the more recent report on the application and effectiveness of the Directive on Strategic Environmental Assessment, COM (2009) 469 describe environmental assessment as 'an important tool for integrating environmental considerations into the preparation and adoption of' those plans and programmes.

Building performance across a broader range of environmental considerations require a comprehensive building assessment methods (Cole, 1999; Ding, 2008). Green building rating systems set a framework of requirements for indentifying, implementing and measuring sustainability and represent a guidance for minimising the adverse effects of buildings, offering a consistent system of comparison to assess performance or expected performance and demonstrate that the building comply with a certain number of declared criteria (Fowler & Rauch, 2006). Rating tools attempt to optimise building performance through continuous improvement which is based on a common set of criteria and targets. They provide professionals with a framework of strategies and best practices to inform the design decision-making process (Reed et al., 2009).

3.2. Airport sustainability appraisal

The research investigate and analyse the issues related to the project design management complying with sustainability criteria. Project design process represents a complex system of decisions made by practitioners from multidisciplinary fields. Therefore methods and tools facilitating information sharing and evaluation are necessary for the effectiveness and efficiency of the decision-making process.

The environmental issues that arise from the development and operation of airport infrastructure relate to noise, air quality, carbon and greenhouse gas emission, use of resources (energy and water), production of waste and use of materials, surface and groundwater pollution, land use and the protection of habitats and biodiversity.

The development of a sustainable airport requires an architectural approach that encompasses not simply the whole airport site, but includes the wider infrastructure into which that airport is embedded. Rating systems represent a valid tool supporting the design process in the evaluation of sustainable strategies and technical approaches. But in order to be efficiently used in the airport infrastructure design they need to be improved through the development of methods and tools that will enable the long-term planning incorporating considerations about the whole infrastructure as it relates to the transport demand, to its social impact – both on the passengers and the surrounding community – and the environmental constraints. All these aspects must be considered in advanced during the design process and properly evaluated in order to inform an integrated and balanced system of architectural/engineering solutions. A new airport rating system could be promoted in planning policies, harmonizing the process of growth and urban transformation with the development of the airport, which should not be considered as an isolated and autonomous entity.

4. Methodology

In order to achieve the proposed objectives, an initial phase of analysis and study has been carried out concerning the airport project design process and the state of the art of regulations, standards and operational and project strategies related to the green building design and the aviation industry. The analysis has been carried on through the scientific literature review and the study of international research results concerning in particular the development of sustainability rating systems. Literature and web review has focused on methods to define, analyse and assess the concept of environmental capacity and sustainable airport development through in-depth study of the impacts arising from airport operations and infrastructure designed to:

- Identify the impacts related to the airport infrastructure development and operation;
- Define how they can act as a constraint to airport growth;
- Indicate methods for assessing their magnitude, forecasting, and monitoring those impacts;
- Examine the infrastructural design, technological, operational and business practices required to minimise those impacts.

Moreover, a series of tutorials, supported by core teaching material (lectures and readers) used by the Centre for Aviation, Transport and the Environment (CATE) of the School of Science and the Environment of the Manchester Metropolitan University (UK) in its undergraduate and post graduate course units on aviation sustainability and environmental management at airports provided a rapid introduction to the topic and detailed background information relating to:

- Environmental capacity constraints at airports;
- Sustainable development and the aviation industry;
- Aircraft noise disturbance and other community impacts;
- Local air quality at airports;
- Management of energy and water consumption;
- Water pollution;
- Waste generation, reduction and treatment;
- Carbon and other greenhouse gas emissions reduction and management;
- Protection of habitats and biodiversity.

In-depth study has been carried to define the airport-wide sustainability index. The study has been focused on the concept of airport environmental capacity: a list of "green airports" case studies has been selected in order to identify methods, tools and best practices complying with sustainability indicators already adopted during the planning, construction, management, maintenance and decommission of European and international airports which include a sustainable vision within their development plans.

A second phase of analysis of the selected case studies is currently going on through interviews, workshops, focus groups and semi-structured questionnaires, in collaboration with the Centre for Aviation, Transport and the Environment, academics, researchers, architects and airport design experts and Airport Industry authorities such as the Italian National Civil Authority (ENAC, Ente Nazionale Aviazione Civile), Eurocontrol and the ACI.

5. GrADE methods and tools

Although many efforts have been made to define sustainability and to identify airport sustainability practices, no broad, industry-adopted system exists to rate airport environmental sustainability design. The result of this study is the application of environmental sustainability criteria in airport design through the support of operational tools. The research defines specific method and tools enabling both design project control and sustainability appraisal. The method is based on systematic process, linked to modeling studies and the development of sustainability indicators that would inform a site-wide and life cycle approach to the design of airport infrastructure.

Such system would help airports evaluate continued sustainability performance; set sustainability goals, objectives; improve internal and external relations; increase their competitive advantage; and help justify sustainability management. The GrADE is based on the following design specifications gleaned from the stakeholder outreach process and from the research stages of study and analysis:

- Incorporate elements of existing rating systems to the extent possible;
- Include a points-based scoring framework;
- Recognize airport-wide sustainability performance;
- Emphasize flexibility to accommodate all airport typology of intervention.

5.1. A method for airport environmental sustainability evaluation

The GrADE method provides participating airports the flexibility to use the system in the way that best suits their needs and resources. Because performance is scored and tracked at the requirement, category, and overall rating system levels, airports can gauge their performance at whichever level of adoption makes them most comfortable, and then progress easily toward a fuller adoption over time. This flexibility allows selective prioritisation of the requirements and categories, as airports can choose which strategies resonate most with their stakeholders and adopt them on a case-by-case basis, or pursue a more comprehensive approach. Within the GrADE framework, seven

categories have been defined, namely noise abatement, emission reduction and air quality, energy use, water use, waste management and materials, water pollution reduction, biodiversity and land use (Table 1). Each category contains a different number of requirements and design specifications. A sheet is provided for each requirement with information regarding:

- purpose of the requirement;
- related requirements within the same or other categories;
- performance indicator;
- architectural and technological strategies for the minimization of the environmental impacts;
- specific standards and regulations.

Table 1. GrADE final set of categories and sheets.

Cat. 1	Noise Abatement
	1. Design airside layout to reduce noise impact
	2. Provide physical mitigation barriers between operating areas and the surroundings
Cat. 2	Emission Reduction and Air quality
	3. Design airside layout to minimise aircraft emissions
	4. Reduce parking footprint
	5. Develop infrastructure to increase public transport
	6. Design infrastructure and buildings to minimise carbon and greenhouse gas emissions
Cat. 3	Energy Use
	7. Design and upgrade buildings to reduce energy consumption
	8. Design to reduce outdoor energy consumption
	9. Use alternative and renewable energy sources
Cat. 4	Water Use
	10. Landscape and design to reduce water use
	11. Design for water efficient use
	12. Design to maximize water harvest, recycle and reuse
Cat. 5	Waste management & Materials
	13. Design to provide storage and collection of recyclables
	14. Design for deconstruction, reuse and recycling
	15. Select recycled, bio-based and rapidly renewable materials
	16. Select materials high design service life, minimising maintenance and replacement cycles
Cat. 6	Water Pollution Reduction
	17. Design to reduce stormwater quantity
	18. Design to improve stormwater quality
Cat. 7	Biodiversity preservation & Land use
	19. Design the layout of infrastructure to avoid destruction of sensitive habitats
	20. Design infrastructure and buildings not to be attractive to some species
	21. Landscape and design to minimise land use and reduce heat island effect
	22. Design and technologies to reduce light pollution

Requirements that target a broader range of sustainability considerations, address sustainability airport-wide, and promote flexible strategies were preferred over those that prescribe a specific avenue to success, because they offer more flexibility and are likely to accommodate evolving techniques and technologies. Similar, narrow strategies have been grouped to prepare a consolidated set of sustainability requirements. This approach will increase flexibility by allowing airports to choose sustainability strategies that are tailored to their organisations, while preserving a high-level objective that they can use to evaluate performance.

The goal of the GrADE method and tools is to help airports identify, evaluate, prioritise, and select sustainability practices for airport capital projects, programs, and operations.

The tools are intended to provide a planning space for users to evaluate strategies and prepare plans that can assist in decision making. To assist in evaluation and prioritisation, a weight is assigned to each of the issue (category) and requirement (sheet). The weights are used to calculate a numerical score for each sustainability practice; the scores can be used to compare the practices to determine which ones meet a user's preferences.

6. Conclusions

The research was focused on the evaluation process of project compliance with green building requirements during preliminary stages of project design. The primary aim of the research was to develop method and tools to check and evaluate the sustainability design performances during the whole project development.

Airports can be constrained by environmental issues which restrict current operations and limit future potential growth. In order to maximise opportunities for growth, it is necessary to consider all the specific factors involved in airport design that can have an influence upon the environmental consequences of its subsequent operations and therefore impact upon integrated sustainability strategies. Life cycle and long-term planning of airport infrastructures also demand a systemic approach to meet the need for change through better definition of the design process and compliance with green building requirements.

GrADE method and its respective tools will contribute in achieving the goal of sustainable development of airport infrastructure providing a methodological framework to measure and monitor environmental sustainability performance and creating new opportunities for the aviation regulatory organisations and airport operators to define architectural and technological strategies to enhance sustainable airport infrastructure design.

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References

ACARE, 2008. Advisory Council for Airport Research in Europe "Addendum to the Strategic Research Agenda".

AIRBUS, 2010. Global Market Forecast 2011–2030 "Delivering the Future".

AIRBUS, 2013. Global Market Forecast 2013–2032 "Future Journeys".

Ali H.H., Al Nsairat S.F., 2009. Developing a green building assessment tool for developing countries: case of Jordan, Building and Environment (44), pp. 1053–1064.

AlWaer, H., Sibley, M., Lewis, J., 2007. Factors and Priorities for Assessing Sustainability of Regional Shopping Centres in the UK, Architectural Science Review, 51:4, 391–402.

Berardi U., 2012. Sustainability assessment in the construction sector: rating systems and rated buildings. Sustainable Development (20), pp.411–424.

Blonigen, B.A., Cristea, A.D., 2012. Airports and urban growth: evidence from quasi-natural policy experiment.

Button, K., Leitham, S., McQuaid, R.W., Nelson, J.D., 1995. Transport and industrial and commercial location, The Annals of Regional Science, 29, 189–206.

Cole, R.J., 2003. Building environmental assessment methods – a measure of success.

Coleman, R.J., 1999. Environmentally sustainable capacity. Proceedings of the ECAC/EU Dialogue with the European Air Transport Industry: Airport Capacity – Challenges for the Future, Salzburg 15–16 April, European Civil Aviation Conference, Neuilly sur Seine, France, pp.118–125.

DEFRA – Department for Environment, Food and Rural Affairs, 2012. Adapting to Climate Change: helping key sectors to adapt to climate change Government Report for the Adaptation Reporting Power, London, available at www.gov.uk/government/publications/adapting-to--climate-change-helping-key-sectors-to-adapt-to-climate-change, accessed 13 July 2013.

DfT – Department for Transport, 2004. The importance of transport in business' location decisions, London.

Ding, G.K.C., 2008. Sustainable construction – The role of environmental assessment tools, Journal of Environmental Management (86), pp. 451–464.

EEA – European Environment Agency, 2007. Climate for transport change. TERM 2007: indicators tracking transport and environment in the European Union, EEA Report No. 1/2009, Copenhagen.

EEA – European Environment Agency, 2012. Climate Change Impacts and Vulnerability in Europe 2012, Copenhagen, available at http://www.energee-watch.eu/sites/default/files/Climate%20change-%20impacts%20and%20vulnerability%20in%20Europe%202012.pdf.

Eurocontrol, 2007. A Place to Stand: Airports in the European Air Network.

Eurocontrol, 2013. Challenges of Growth 2013 Summary Report, Eurocontrol, available at: https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/reports/201307-challenges-of-growth-summary-report.pdf.

European Commission, 1998. The Common Transport Policy. Sustainable Mobility: Perspectives for the Future, Commission Communication to the Council, European Parliament, Economic and Social Committee and Committee of the Regions, DG VII. Brussels: European Commission.

European Commission, 2011. Airport policy in the European Union – addressing capacity and quality to promote growth, connectivity and sustainable Mobility, COM(2011) 823, available at http://ec.europa.eu/transport/modes/air/airports/doc/2011-airport-package--communication_en.pdf.

European Commission, 2013. Annual Analyses of the EU Air Transport Market 2012. Executive summary, Croydon.

European Commission, 2014. Horizon 2020 in brief. The EU Framework Programme for Research & Innovation, Luxembourg.

Forsberg A, von Malmborg F., 2004. Tools for environmental assessment of the built environment. Building and Environment (39), pp. 223–238.

Fowler, K.M. & Rauch, E.M., 2006. Sustainable Building Rating Systems Summary. Contract, (July 2006), pp.1–55.

Haapio, A. and Viitaniemi, P., 2008. A critical review of building environmental assessment tools, Environmental Impact Assessment Review (28), pp. 469–482.

Kibert CJ., 2005. Sustainable construction: green building design and delivery. New Jersey, United States of America: John Wiley & Sons.

Knippenberger, U., Wall, A., 2010. Airports in cities and region. Research and practice, Universität des Landes Baden-Württemberg und nationals, Karlsruhe.

Malmqvist et Alii, 2011. A Swedish environmental rating tool for buildings, Energy 36, 1893e1899.

Mateus, R. & Bragança, L., 2011. Sustainability assessment and rating of buildings: Developing the methodology SBToolPT-H. Building and Environment, 46(10), pp.1962–1971. Available at: http://dx.doi.org/10.1016/j.buildenv.2011.04.023.

National Air Traffic Services, 2011. Climate Change Adaptation Report, Issue 1.0; available at: http://archive.defra.gov.uk/environment/climate/documents/adapt-reports/08aviation/nats-climate-change-report.pdf.

Reed R, Bilos A, Wilkinson S, Schulte K-W., 2009. International comparison of sustainable rating tools. Journal of Sustainable Real Estate (1), pp.1–22.

Robichaud, L.B., Anantatmula, V.S., 2011. Greening Project Management Practices for Sustainable Construction, journal of Management in Engineering (27), pp. 48–57.

Sheate W, Dagg S, Richardson J, Aschemann R, Palerm J, Steen U., 2003. Integrating the environment into strategic decision-making: conceptualizing policy SEA. Eur Environ;13(1):1–18.

Steinemann A., 2001. Improving alternatives for environmental impact assessment. EIA Rev;21(1): 3–21.

Thomas, C., 2013. Aviation and its environmental impacts, Manchester Metropolitan University.

Thomas, C., Hooper, P., 2011. Sustainable Development and Environmental Capacity of Airports, in Ashford, N.J., Mumayiz, S., Wright, P.H., 2011. Airport Engineering. Planning, Design, and Development of 21st Century Airports, Fourth Edition.

Thomas, C., Hooper, P., Raper, D., 2010. Air transport in an environmentally constrained World, Journal of Airport Management, 5(1): 4–6.

Thomas, C., Upham, P., Raper., D., 2001. Environmental capacity of aviation: theoretical issues and basic research directions. Journal of Environmental Planning and Management 44 (5), 721–734.

Thomas, C.S., Hume, K.I., Hooper, P.D. 2004. Aircraft Noise, Airport Growth and Regional Development, in Proceedings of the Royal Aeronautical Society/American Institute of Aviation Acoustics Conference, Manchester, May 10–12.

Trinder, D., 2001. Transport Infrastructure and Economic Growth, Structural Issues Development Group Working Paper 01(06).

Upham, P., Thomas, C., Raper, D., Gillingwater, D., 2003. Environmental capacity and airport operations: current issues and future prospects, Journal of Air Transport Management 9, p: 145–151.

Whyte, J., 2012. Building Information Modeling in 2012: Research Challenges, Contributions, Opportunities, Design Innovation Research Centre, working paper 5(1.01).

Woudsma, C., Jensen, J.F., 2003. Transportation's influence on land use development: a historical spatial-temporal approach.

Zografos, K.G., Madas, M.A., 2006. Development and demonstration of an integrated decision support system for airport performance analysis, Transportation Research Part C (14), 1–17.