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GrADE – Green Airport Design Evaluation

Methods and tools for the environmental sustainability appraisal at the early stage of international civil airport design

Settore disciplinare prevalente: ICAR 12

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I. Collocazione scientifica della tesi

La ricerca si colloca nell'area scientifico-disciplinare 08-C1 DESIGN E PROGETTAZIONE TECNOLOGICA DELL'ARCHITETTURA, individuata come settore di ricerca che, attraverso un approccio esigenziale-prestazionale, porta alla definizione di strumenti e metodi per la progettazione sostenibile degli edifici e la gestione dei requisiti prestazionali durante l'intero processo progettuale, la valutazione critica delle alternative di progetto ed i controlli della qualità architettonica ed ambientale.

II. Parole chiave

gestione del progetto, prestazioni, approccio integrato, progetto aeroportuale , *green building, sustainability index,* capacità ambientale, strumenti di supporto decisionale

III. Base di partenza scientifica nazionale e internazionale

III.1 Stato dell'arte: quadro di riferimento e campo di indagine

La ricerca affronta le problematiche relative alla produzione del progetto ed ai processi di sviluppo che si materializzano nella progettazione e che influenzano la qualità del prodotto finale. La questione rientra nell'ambito di applicazione del Programma Europeo *Horizon 2020 Framework* e della *roadmap* italiana che hanno come obiettivo principale quello di colmare il divario tra ricerca, diversi settori industriali e del mercato a sostegno dello sviluppo di tecnologie e processi sostenibili.

La molteplicità dei processi da integrare durante lo sviluppo progettuale richiede metodi e strumenti di governo che possano gestire insiemi di variabili che caratterizzano la complessità degli interventi. La gestione dell'informazione associata a sistemi parametrici riguardanti le prestazioni relative alla sostenibilità svolgono un ruolo chiave in termini di innovazione contribuendo ad anticipare, già nelle fasi preliminari del processo, le scelte che influiscono sui livelli prestazionali dei risultati dell'intervento.

Gli aeroporti rappresentano dei nodi critici nella rete dei trasporti ed hanno un ruolo vitale nello sviluppo socio-economico delle aree in cui sono insediati. Le previsioni di traffico delineano una crescita continua con conseguente necessità di ampliamento e sviluppo degli aeroporti sia a livello operativo che infrastrutturale. In Europa la situazione è particolarmente critica vista la scarsa disponibilità di aree potenzialmente idonee o adibite alla crescita dell'infrastruttura. La situazione è resa ancor più critica dalle limitazioni alle attività aeroportuali derivanti dal superamento dei livelli minimi e degli standard accettabili in relazione all'impatto

ambientale. Ciò influisce – oltre che sull'operatività (ad esempio con i limiti di volo nelle ore notturne) - anche sull'approvazione dei piani di sviluppo ed ampliamento degli aeroporti.
La valutazione di tali impatti e delle strategie progettuali e tecnologiche per la loro riduzione e/o eliminazione rappresenta una priorità nelle fasi di avvio della pianificazione e progettazione di nuove infrastrutture o dell'ampliamento di quelle esistenti.

Negli ultimi due decenni, per verificare e garantire la qualità di un progetto sostenibile, sono stati sviluppati metodi di valutazione del livello di sostenibilità (BREEAM, LEED, Protocollo ITACA, CASBEE, GBTool, etc.). Tali metodi, che dapprima rappresentavano solo uno strumento di analisi delle prestazioni ambientali e riconoscimento degli edifici *green*, oggi stanno evolvendo in sistemi che associano l'obiettivo della certificazione con quello della reale gestione delle prestazioni in fase progettuale, fornendo una piattaforma strutturata per la definizione degli obiettivi da perseguire e dei requisiti cui il progetto dovrà rispondere.

III.2 Delimitazioni del problema scientifico

La ricerca si inserisce nell'ambito di indagine e analisi delle problematiche relative alla gestione del processo progettuale per la sostenibilità che, in quanto complesso sistema di scelte assunte con il contributo di figure tecnico-professionali provenienti da settori multidisciplinari, rappresenta un ambito nel quale risultano fondamentali le tecniche e le procedure atte a facilitarne la condivisione e l'integrazione.

La ricerca si propone di sviluppare metodi e strumenti per la definizione delle prestazioni e delle strategie e tecnologie progettuali relative alla sostenibilità ambientale.
La decisione di focalizzare la ricerca nel settore aeroportuale è giustificata dal fatto che le aerostazioni, a differenza delle altre tipologie di costruzioni, presentano caratteristiche sistemiche internazionalmente riconosciute. Esse sono legate sia alla progettazione dell'infrastruttura in sé (pianificazione del progetto con una visione LCD - Life Cycle Design), sia alla presenza contemporanea di competenze diverse ed altamente specializzate nel team di progetto, sia dal considerevole insieme di prestazioni da raggiungere (efficienza operativa, sicurezza, ambiente, costi, gestionali, etc.), che al delicato rapporto che lega queste strutture con il territorio, in relazione ai sistemi territoriali e socio-economici con i quali interagisce ed agli aspetti di sostenibilità conseguenti.

Lo studio è volto in prima istanza ad indagare le problematiche ambientali che emergono dallo sviluppo ed operatività delle infrastrutture aeroportuali. Tali problematiche riguardano il rumore, la qualità dell'aria, le emissioni di carbonio e gas serra, l'adattamento ai cambiamenti climatici, l'uso di risorse (energia e acqua), la produzione di rifiuti e l'utilizzo dei materiali, l'inquinamento delle acque di falda e di superficie, l'utilizzo del suolo e la salvaguardia degli habitat e della biodiversità.

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III.4 Fonti – Contatti principali

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- Colin Ward (architect and partner), Foster & Partners

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IV. Obiettivi generali e obiettivi specifici della ricerca

L'obiettivo generale della ricerca consiste nell'individuazione delle problematiche ambientali legate alla operatività e allo sviluppo delle infrastruttura aeroportuali che permetta di delineare i criteri di valutazione delle strategie progettuali e tecnologiche nelle fasi di avvio della programmazione e pianificazione degli interventi. In particolare:

- Delineare lo scenario di sviluppo delle infrastrutture aeroportuali individuando le problematiche che emergono nella definizione delle strategie per la sostenibilità ambientale e dell'impatto che esse hanno;

- Definire un *framework* dei requisiti prestazionali nell'ambito della progettazione aeroportuale volte alla minimizzazione e riduzione degli impatti;
- Individuare le caratteristiche spaziali e funzionali delle modalità di accesso all'aeroporto e dei relativi livelli di impatto.

L'obiettivo specifico della ricerca consiste nella definizione di un sistema di valutazione in cui ai requisiti prestazionali vengano associate le strategie per la riduzione o eliminazione degli impatti e i relativi livelli prestazionali. In particolare:

- Definizione dell'insieme di strategie progettuali e tecnologiche atte alla riduzione degli impatti ambientali;
- Individuazione dei criteri di valutazione relativi ad ai requisiti specifici individuati nel corso della ricerca
- Sviluppo di procedure e strumenti per valutare sul campo degli aeroporti la metodologia di progettazione integrata ed avanzata sul piano prestazionale nonché i requisiti relativi alla sostenibilità ambientale.

V. Descrizione del programma di ricerca

V.1 Modalità di svolgimento

Nell'intento di perseguire gli obiettivi proposti, il programma di ricerca ha previsto une prima fase di analisi e approfondimento delle caratteristiche del processo progettuale relativo allo specifico settore di riferimento e dello stato dell'arte nella definizione delle normative e delle strategie progettuali, operative ed economiche relative al *green building design*.
Attraverso l'attività di ricerca è stata individuata la necessità di definire un modello metodologico per la valutazione delle *performance* di sostenibilità ambientale specifico per l'*airport design*. L'attività di ricerca è stata inoltre affiancata a quella didattica attraverso la proposta di un modulo formativo nell'ambito del Laboratorio di progettazione ambientale: tale esperienza ha permesso un riscontro delle metodologie e dei contenuti di ricerca proposti in relazione alla valutazione delle strategie tecnologiche in conformità con i requisiti di sostenibilità nelle fasi di avvio del processo progettuale.
L'attività di ricerca svolta presso il *Centre for Aviation, Transport and the Environment* (CATE) presso la School of Science and Engineering della Manchester Metropolitan University (UK), ha dato l'opportunità di interagire con docenti e ricercatori provenienti da settori disciplinari diversi da quello di appartenenza, con professionisti – architetti ed ingegneri – esperti nella progettazione aeroportuale (ARUP, Foster+Partners, Grimshaw) e con gli operatori del settore (Manchester Airport Group). Tale esperienza ha garantito un *background* multidisciplinare a supporto delle successive fasi di definizione dei prodotti della ricerca e ha permesso di validare l'applicazione di alcune metodologie (workshop, *charette, focus group*) per la raccolta dei dati a supporto dell'attività di ricerca. Una ulteriore fase di dialogo e riscontro con operatori e gestori aeroportuali (Fiumicino, Manchester, Amsterdam, etc.) e gli enti di regolamentazione a livello europeo (Airport Council International, Eurocontrol) è avvenuta tramite interviste e la somministrazione di un questionario strutturato.

Al di là degli obiettivi specifici della ricerca, tali attività hanno accresciuto la consapevolezza del ruolo di dottorando/ricercatore nel creare un dialogo tra diversi settori disciplinari al fine di incrementare le proprie competenze specialistiche e, a livello più ampio, di architetto/tecnologo come valida interfaccia tra gli operatori, gli *stakeholder* e gli esperti coinvolti nel processo decisionale del progetto delle infrastrutture aeroportuali.

V.2 Fase istruttoria

Durante la fase istruttoria è stato circoscritto il problema scientifico ed individuati i principali campi di indagine da esplorare (la gestione del progetto, i sistemi di valutazione e certificazione della sostenibilità ambientale e le caratteristiche del progetto aeroportuale). Questo ha permesso di individuare le informazioni utili ai fini di una conoscenza sistematica del problema, identificando al tempo stesso gli strumenti e le risorse disponibili e definendo gli obiettivi principali ed i metodi attraverso i quali sviluppare la ricerca.

V.3 Fase di analisi

Una prima fase di analisi indiretta è stata finalizzata all'indagine e allo studio di fonti che hanno permesso di acquisire le conoscenze basilari e indispensabili per un corretto inquadramento del problema scientifico e dello stato dell'arte relativo allo sviluppo di metodologie e strumenti per la gestione dei progetti sostenibili e la definizione di strumenti di valutazione sperimentali. A tali conoscenze si ascrivono:

- un esame dettagliato dei sistemi di certificazione attualmente più diffusi (BREEAM, LEED);
- l'analisi di modelli di certificazione orientati alla valutazione degli aeroporti – sviluppati da gestori aeroportiali (ad es. Chicago Department of Aviation) o da centri di ricerca specializzati (ad es. Airport Cooperative Research Programme);
- lo studio della letteratura scientifica e dei risultati delle ricerche a livello internazionale;
- l'approfondimento delle norme tecniche relative alla progettazione aeroportuale, alla gestione del progetto e agli standard e parametri per la valutazione dei livelli di sostenibilità edilizia.

Inoltre sono stati analizzati i metodi, gli strumenti e le *best practice* adottate nella pianificazione, progettazione, costruzione, gestione, manutenzione e dismissione delle infrastrutture aeroportuali che integrano una visione sostenibile all'interno dei propri piani di sviluppo.

Una seconda fase di analisi è volta all'indagine diretta di alcuni casi studio attraverso interviste, workshop, *focus group* ed un questionatio strutturato messi a punto con gli operatori (enti di regolamentazione, gestori, progettisti, etc.) del settore aeroportuale e a specialisti e ricercatori nel settore della valutazione degli impatti ambientali delle infrastrutture aeroportuali, per assicurare che i prodotti proposti dalla ricerca fossero adeguati alle richieste.

V.4 Fase propositiva

Nella fase propositiva sono stati delineati i contenuti degli strumenti (schede) per la gestione dello sviluppo progettuale del *green airport design* e la valutazione delle scelte progettuali atte al soddisfacimento dei requisiti di sostenibilità nell'ambito della progettazione aeroportuale. Il prodotto della ricerca è un modello metodologico che definisce procedure e strumenti relativi alle strategie progettuali degli aeroporti.
Il modello contiene schede specifiche per l'organizzazione dei parametri a supporto dei processi di decisione necessari sin dalle prime fasi del processo progettuale. Le schede sono organizzate in categorie corrispondenti alle problematiche ambientali analizzate nelle fasi di ricerca precedenti.
A ciascuna categoria e scheda, sono associati dei valori che ne permettano la valutazione. Attraverso l'individuazione di alcune schede esemplificative, vengono inoltre proposti i livelli di valutazione delle prestazioni stabiliti all'interno della scheda stessa.

In questo modo, il modello si configura secondo un doppio sistema di valutazione:

1) a livello generale, categorie e schede hanno un "peso" definito dai valori ad essi associati in base alla magnitudine del problema ambientale (per quanto riguarda le categorie) e l'efficacia e applicabilità delle strategie proposte (per quanto riguarda le schede). Tale sistema di valutazione deriva in prima istanza dalle osservazioni ed impotesi avanzate in fase di analisi e poi supportate dal questionario sottoposto alle divisioni tecniche e ambientali all'interno dei maggiori aeroporti europei. Attraverso l'applicazione di questa metodologia a casi specifici – e supportata dagli enti di controllo nazionali ed internazionali – sarà possibile adattare il sistema di valutazione ai diverse tipologie di aeroporto (per dimensione, localizzazione, geomorfologia del territorio, constesto socio-economico, etc.);
2) a livello di ciascuna scheda, viene invece definito un sistema di valutazione che deriva dall'analisi delle normative di riferimento, dei casi studio presi in esame e dei parametri (*Key Performance Indicator, benchmark, baseline*) per stabilire le varie "soglie" di valutazione. Rispetto alla valutazione a livello generale, quella delle schede è passibile di essere modificata, solo in caso di necessario adeguamento agli aggiornamenti normativi, tecnologici e/o specifici rispetto alle modalità di valutazione.

VI. Risultati attesi: rilevanza scientifica, innovazione e utilità della ricerca

Nel perseguire obiettivi di sostenibilità assumono una rilevanza crescente i meccanismi di processo, da interpretarsi e risolversi in un'ottica sistemica. A maggior ragione nella progettazione delle infrastrutture aeroportuali, l'esigenza di razionalizzare il processo progettuale ha determinato la necessità di sviluppare metodologie e strumenti operativi atti ad incrementare le capacità di pianificazione, di gestione e di controllo, che supportino in maniera efficace ed efficiente il raggiungimento degli obiettivi che il progetto si prefigge con le risorse disponibili.
La ricerca appare efficace nel proporre l'integrazione di metodologie e strumenti operativi, non limitati alla mera automazione della produzione degli elaborati, in

quanto fattore fondamentale nell'ambito del processo di progettazione sistemico come quello aeroportuale, che può incidere significativamente sulle prestazioni del prodotto finale e determinare il successo di un *green airport*. Le metodologie e gli strumenti di gestione del progetto, attraverso modelli di condivisione delle informazioni che rappresentano la conoscenza di base del progetto, hanno infatti la funzione di sostenere in modo mirato le esigenze del gestore e il raggiungimento degli obiettivi del progetto diminuendo il consumo delle risorse disponibili con tempi e costi proiettabili nel ciclo di vita.
A livello internazionale manca una definizione riconosciuta di un sistema di valutazione specifico per le infrastrutture aeroportuali. Una proposta è stata recentemente avviata (dicembre 2014) negli Stati Uniti da parte dell'Airport Cooperative Research Programme che ha dimostrato l'interesse e la necessità da parte del settore di un modello condiviso per la valutazione della sostenibilità degli aeroporti. A livello europeo manca una proposta di questo tipo e la ricerca ha proposti di farlo supportata dal dialogo e affiancamento con uno dei maggiori centri di ricerca a livello internazionale sulla valutazione degli impatti ambientali degli aeroporti e con gli operatori del settore aeroportuale (a livello nazionale ed europeo). Nello specifico lo studio ha definito un ampio set di parametri di sostenibilità idonei focalizzando sul tema centrale della capacità (operativa ed infrastrutturale) ed associandovi l'originale concetto di capacità ambientale cui la ricerca ha dato concretezza e strumenti.
Il prodotto della ricerca trova la sua applicabilità come modello di valutazione e certificazione delle infrastrutture aeroportuali da parte dei gestori aeroportuali e degli enti europei di controllo e regolamentazione (Eurocontrol, Airport Council International).

VII. Destinatari privilegiati e spendibilità della ricerca, possibili enti terzi finanziatori

I destinatari privilegiati dai risultati della ricerca e coinvolti nei possibili sviluppi futuri e nel finanziamento di ulteriore attività di ricerca sono gli enti di regolamentazione del settore aeroportuale – a livello nazionale (e.g. ENAC – Ente Nazionale Aviazione Civile) ed internazionale (e.g. ACI – Airport Council International, Eurocontrol) – preposti all'autorizzazione, controllo e coordinamento dei programmi di intervento nonché ai gestori aeroportuali in quanto responsabili delle individuazione degli indirizzi di intervento si sostenibilità ambientale (e definizione del documento preliminare alla progettazione).
Altri destinatari ai quali è diretta la ricerca sono i progettisti e consulenti che si occupano di progettazione aeroportuale interessati allo sviluppo e utilizzo di metodologie di gestione dei criteri di sostenibilità, nonché il settore scientifico di riferimento che potrà sviluppare le metodologie applicate in questa ricerca per la definizione di strumenti applicabili ad altri settori della progettazione.

VIII. Sviluppi futuri della ricerca

Nell'ottica della sostenibilità la proposta di metodologie e strumenti automatizzati rappresenta una buona pratica per il sistema aeroportuale sempre aperto a revisioni e implementazioni continue dettate dallo sviluppo delle tecnologie, dall'aggiornamento delle normative e dall'evoluzione dell'approccio progettuale stesso alle tematiche della sostenibilità.

Successivamente alla ulteriore verifica applicativa dei risultati della ricerca, il quadro delle strategie progettuali e tecnologiche suggerite dalla ricerca potrebbe essere integrato con le strategie tecnico-operative e manageriali del settore volte anch'esse alla riduzione ed eliminazione degli impatti ambientali. In quest'ottica, il modello finale si presterebbe ad essere recepito in ambito europeo e nazionale come sistema di verifica ed accreditamento riconosciuto (come ad esempio è il caso del *Airport Carbon Accreditation* che valuta e certifica vari livelli di sostenibilità relativi alla riduzione delle emissioni di carbonio).
In un panorama nel quale è necessario che le strategie progettuali, tecnologiche e gestionali siano green-oriented, l'utilizzo di strumenti automatizzati per attuare tali strategie rappresenta una possibilità concreta. Un ulteriore ambito di sviluppo è perciò costituito dall'integrazione tra il processo decisionale/progettuale in campo aeroportuale già finalizzato agli obiettivi green e i modelli BIM affermati in ambito internazionale. Possibili sviluppi futuri della ricerca sono quindi finalizzati alla elaborazione di sistemi automatizzati integrabili con il BIM(M) (Building Information Modeling & Management) e con i software di simulazione idonei al settore aeroportuale.

IX. Indice ragionato della tesi dottorale completo di bibliografia tematica di ciascun capitolo

IX.0 Introduzione

La ricerca per la gestione del progetto ha un impatto diretto sui processi di progettazione, influenzando lo sviluppo del prodotto per l'attenzione posta agli aspetti di gestione della informazione durante le fasi progettuali. L'opportunità di diffondere e la capacità di gestire le informazioni in forma integrata influenzano reciprocamente l'efficienza ed efficacia dei processi, ma anche la loro capacità di raggiungere gli obiettivi di sostenibilità che implicano una visione integrata sin dalle fasi iniziali del processo progettuale. In particolare quando il concetto di sostenibilità è inteso in termini di salvaguardia ambientale integrata con le valutazioni economiche e di impatto a livello sociale.
La ricerca si propone di sviluppare metodi e strumenti per la definizione delle prestazioni e delle strategie e tecnologie progettuali relative alla sostenibilità ambientale e la verifica degli obiettivi. Tali metodi consentano una gestione collaborativa del processo progettuale, abilitando la condivisione delle informazioni, e di avere un riscontro lungo l'intero sviluppo di un programma d'intervento potendo anche coinvolgere, pariteticamente e sin dalle prime fasi del processo decisionale - dove ciò sia consentito dalle norme - la committenza pubblica, i progettisti e le imprese.

PARTE I – *AIRPORT INFRASTRUCTURE*

IX.1 Capitolo I.1 – *Airports development scenario*

La comunicazione della Commissione europea COM (2011) 823 "La politica aeroportuale nell'Unione europea: assicurare capacità e qualità atte a promuovere la crescita, la connettività e la mobilità sostenibile", affronta il problema della sostenibilità delle infrastrutture aeroportuali proponendo un sistema europeo di regolamentazione che deve affrontare tre sfide: capacità, qualità e ambiente. Le azioni principali sono finalizzate al miglioramento delle performance di volo, la tecnologia dei sistemi aerei moderni, la gestione efficace del traffico. Ma ulteriori interventi a livello infrastrutturale possono essere organizzati tramite l'utilizzo di standard ambientali anche all'interno della progettazione, costruzione, esercizio, manutenzione e dismissione del terminal e dell'intera infrastruttura aeroportuale.

IX.2 Capitolo I.2 – *The airport terminal design as research field of green performance evaluation*

Obiettivi e livelli di *performance* per l'aeroporto e piani per il raggiungimento di tali obiettivi non sono più limitati ai problemi del traffico aereo, ma riguardano anche l'infrastruttura a terra e l'*airport layout plan*. Il progetto dell'aeroporto - in quanto infrastruttura composta da specifici spazi funzionali ed integrata con il territorio circostante (accessibilità, investimenti delle imprese, ritorno sociale, etc.) - richiede molti livelli di analisi e valutazione per individuare i vincoli di sviluppo e gli impatti sull'ambiente a scale diverse e in funzione della capacità di traffico (e quindi del relativo bacino di utenza). La pianificazione a lungo termine deve necessariamente tenere conto dei vincoli ambientali e di come questi interagiscano e influenzino gli aspetti operativi, economici e sociali in relazione alle attività svolte e agli scenari di incremento dell'operatività e sviluppo dell'infrastruttura sul territorio.

PARTE II – *ENVIRONMENTAL SUSTAINABILITY DEFINITION AND EVALUATION*

IX.3 Capitolo II.3 – *Environmental sustainability evaluation*

Il processo di progettazione integrata rappresenta un elemento fondamentale del *green airport design*. Per raggiungere questo scopo è sempre più importante l'integrazione dei metodi di progettazione e strumenti idonei.
Ricerche specialistiche indicano che i cambiamenti climatici e lo sviluppo delle grandi infrastrutture avranno un impatto sempre maggiore sulla pianificazione urbana, così come sui modelli di sviluppo economico e sociale. Il delicato rapporto tra le infrastrutture aeroportuali con il territorio e con gli altri sistemi e il conseguente impatto ambientale, necessariamente impone le istanze di sostenibilità ambientale, sociale ed economica (secondo quello che viene individuato come *Triple Bottom Line* (TBL) *framework*).
Questo scenario ha portato alla crescente domanda di "costruire verde", concentrandosi sul ruolo dei sistemi di certificazione della sostenibilità. L'applicazione di modelli quali il LEED (Leadership in Energy and Environmental Design) e il BREEAM (*Building Research Establishment Environmental Assessment Method*) hanno rappresentato l'incentivo e il supporto in relazione alla progettazione sostenibile. Per trasferire in modo efficace questi modelli all'*Airport Design* risulta perciò necessario fare riferimento ai criteri di sviluppo e al sistema di impatti specifici del settore.
I maggiori aeroporti internazionali si sono dotati di politiche e sistemi di gestione ambientali con l'obiettivo di sviluppare sistemi di pianificazione e gestione delle infrastrutture che risultassero ecologici, efficienti e sostenibili. La sostenibilità

diventa parte integrante delle strategie di business aeroportuale per garantire un equilibrio ottimale tra crescita economica, benefici sociali e la responsabilità ambientale, mediante una pianificazione a lungo termine che concilia i piani di investimento dei capitali con le strategie di adattamento ai cambiamenti climatici, i progressi nella progettazione ambientale, le innovazioni tecnologiche e l'evoluzione di normative e standard di riferimento.
L'indagine delle politiche, metodologie e degli strumenti per la progettazione sostenibile delle infrastrutture aeroportuali permetterà un confronto con le pratiche correnti messe in atto dai gestori e dagli operatori del settore aeroportuale consentendo la finalizzazione del modello metodologico e degli strumenti proposti dalla ricerca.

IX.4 Capitolo II.4 – *Airport environmental sustainability: defining the framework of requirements*

La necessità di ampliamento delle infrastrutture aeroportuali può essere in conflitto con gli aspetti ambientali e logistici in relazione al territorio e alla pianificazione a livello urbano. Gli aeroporti hanno però la capacità di rimodellare la localizzazione delle attività economiche e indirizzare i trend di sviluppo urbano. Pertanto le strategie per lo sviluppo del trasporto aereo devono essere considerate una priorità e integrate nel contesto delle più ampie strategie di sviluppo economico e delle infrastrutture di una regione.
Questi aspetti sono spesso vero collo di bottiglia con ritardi e rischi per la realizzazione dei piani di sviluppo delle infrastrutture, se non attentamente valutati sin dalle fasi iniziali della pianificazione aeroportuale. Gli aeroporti sono stati progettati in funzione di due fattori principali: la capacità di flusso di passeggeri in relazione all'operatività dei mezzi di trasporto aerei e la necessità di standardizzazione imposta dalla normativa tecnica internazionale per l'interoperabilità tra aeroporti di paesi diversi. In tutto il mondo la progettazione dell'infrastruttura aeroportuale segue le stesse metodologie, standard e riferimenti tecnici normativi strettamente dipendenti dalle esigenze funzionali ed operative del trasporto aereo.
Date queste premesse, è evidente come la proposta di un modello metodologico a supporto del Green Airport Design, debba tener presente tutti i fattori coinvolti nella progettazione delle infrastrutture aeroportuali ai fini di una efficace ed integrata valutazione di conformità rispetto ai requisiti di sostenibilità.

IX.5 Capitolo II.5 – *Survey: the role of architectural design in the airport environmental sustainability*

Ai fini della ricerca è stato fondamentale consultare rappresentati del settore air portuale attraverso un questionario strutturato. L'approccio sistematico e strutturato con i manager e pianificatori che oprano all'interno delle divisioni

tecniche degli aeroporti è stato utile ad ottenere un riscontro specialistico riguardo alle problematiche ambientali che influenzano la progettazione delle infrastrutture aeroportuali e la definizione dei requisiti progettuali e tecnologici atti a minimizzare tali impatti.

L'obiettivo del questionario è stato quello di ottenere una valutazione da parte di un campione di partecipanti scelti – individuati selezionando gli aeroporti europei caratterizzati da traffico aereo internazionale e con un numero di passeggeri superiore al milione registrati nel 2014 – sulle strategie tecnologiche e progettuali per la riduzione dell'impatto ambientale.

PARTE III – *GREEN AIRPORT DESIGN EVALUATION (GrADE)*

IX.6 Capitolo III.6 – *GrADE methods and tools*

La regolamentazione europea sulle emissioni di carbonio e gas serra, gli obiettivi di risparmio energetico e l'aumento della quota dell'uso delle risorse rinnovabili sempre più richiedono cambiamenti sistematici nella gestione del processo di progettazione e dei requisiti *green building* ai quali conformarsi. L'integrazione di metodologie e strumenti operativi rappresenta un fattore fondamentale nell'ambito del processo di progettazione complesso come quello aeroportuale, che può incidere significativamente sulle prestazioni del prodotto finale e determinare il successo del *green airport design*. Le metodologie e gli strumenti di gestione del progetto, attraverso modelli di condivisione delle informazioni, hanno infatti la funzione di sostenere in modo mirato le esigenze del gestore e degli utilizzatori (passeggeri, compagnie aeree, etc.) e il raggiungimento degli obiettivi del progetto diminuendo il consumo delle risorse disponibili con tempi e costi prestabiliti nel ciclo di vita.
Il prodotto della ricerca di tesi sarà un modello metodologico ed un insieme di procedure e strumenti applicabili in processi di progettazione. Gli strumenti consistono in una serie di schede contenti indicazioni riguardo:

- scopo e definizione dei requisiti di riferimento
- requisiti e alle strategie tipologiche, tecnologiche e gestionali per la riduzione dell'impatto delle infrastrutture aeroportuali sull'ambiente;
- riferimenti normativi e ad altre fonti (documenti prodotti dagli enti aeroportuali, risultati di ricerche internazionali, etc.);
- indicazione dei criteri di valutazione generali;
- indicazioni delle schede correlate all'interno della stessa categoria o di categorie diverse.

Le schede sono raccolte nelle sette categorie proposte (riduzione del rumore, riduzione delle emissioni e qualità dell'aria, uso dell'energia, uso dell'acqua, gestione dei rifiuti e utilizzo dei materiali, riduzione dell'inquinamento delle acque, tutela della biodiversità ed utilizzo del suolo).

IX.7 Conclusioni

With its leading knowledge and manufacturing capability, the European aviation industry is in a position to define and shape a sustainable future. […] Today and even more so tomorrow, a safe and efficient Air Transport System, led by innovative technology, will be a vital vector for our economy, our society and the cohesion of Europe and the world (European Commission, 2011).
Combinando le conoscenze avanzate e innovative nel settore della tecnologia con un sistema coerente di norme e standard, sarà possibile pianificare e gestire lo sviluppo di un settore in continua evoluzione come quello dell'aviazione, legato

alla variabilità dell'economia globale, al continuo aggiornamento delle tecnologie, alla costante crescita della domanda di traffico ed ai vincoli ambientali legati alla gestione e allo sviluppo delle infrastrutture aeroportuali.
Futuri scenari di ricerca saranno perciò caratterizzati dal contributo multi-disciplinare in ambito accademico e di contatto diretto con gli operatori del settore e con gli enti di regolamentazione a livello europeo ed internazionale.

INTRODUCTION

I Abstract and keywords

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

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.

A number of tools using sustainability indicators have been developed in the last two decades. International green building rating systems such as BREEAM, LEED, and others have been used as an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes. But the individual buildings that comprise a major part of the airport infrastructure are often not, on their own, the critical elements that determine the longer term sustainability of the site.

An in-depth study has been carried out to define an airport-wide sustainability index. The study has been focused on the concept of *airport environmental capacity*[1] and the good practices complying with sustainability indicators already adopted during the planning, construction, management, maintenance and decommission of European and international airports.

The research defines specific method and tools enabling both design project control and sustainability appraisal. The method is based on systematic process, linked to the development of sustainability indicators that would inform a site-wide approach to the design of airport infrastructure.

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.

[1] The operational capacity of an airport can be constrained to below its infrastructure capacity if the environmental consequences of its operation exceed environmental regulatory limits, public acceptability or the airport is unable to secure adequate supplies of resources to meet customer service requirements.

Keywords: project design management, performance based design, integrated approach, green building, sustainability index, airport design, environmental capacity evaluation, decision support tool

II Scientific field

The proposed study applies a perfomance-based approach for the definition of method and tools for the sustainable buildings design and the performance requirements management since the early stages of airport design. These method and tools are also aimed to support the critical evaluation of design alternatives and to check the quality of the final product.
The research scientific field is *ICAR/12 Tecnologia dell'Architettura* (Architectural Technology) within the macro-area *08-C1 Design e Progettazione Tecnologica dell'Architettura* (Design and Architectural Technology), as defined by the Italian ministry *Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR)* in the Ministerial Decree No. 249/2000.

III Scientific background

III.1 State of the art: frame work and investigation field

The research investigation focuses 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*[2] 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.

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.

[2] *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).

Airports are critical nodes in the transport system and can have a vital role in supporting the socio-economic development of city regions. Forecasts outline a steady growth of the air traffic demand resulting in the need of expansion and development of the operational and infrastructural capacity of airports. 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 and the difficulty of securing planning approval for new airport infrastructure development. Airports are also constrained by environmental issues which restrict current operations and limit future growth potential.
Therefore the evaluation of environmental issues and the selection of design and technological strategies for minimising and/or reducing those impacts represents a priority in the early stages of planning and design of new infrastructure or of the expansion of the existing ones.

A number of tools using sustainability indicators have been developed in the last two decades. International Green Building rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), CASBEE (Comprehensive Assessment System for Built Environment Efficiency), GBTool (Green Building Tool), Protocollo ITACA (*Istituto per l'Innovazione e Trasparenza degli Appalti e la Compatibilità Ambientale*), and others have been used as an effective framework for assessing building environmental performance and integrating sustainable development into building design and construction processes. These models, which initially represented only a tool for the analysis and recognition of the environmental performance of green buildings, today are evolving into systems that combine the certification objective with that of the real performance management during the design process, providing a structured platform for the definition of the green project requirements and the performance measures to guide the sustainable design.

III.2 Scientific problem statement

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 research application field is the airport infrastructure design. The critical relationship between these infrastructures and the territory and other systems, and the resulting environmental impact, necessarily impose environmental, social and economic sustainability instances as the core of the project development. Airport project has an evolving nature and is organised into typical and internationally adopted phases (i.e. brief, master plan, concept, preliminary and final design, detailed design, operational project, as-built project, disposal). These characteristics require the combined collaboration of different skills and highly specialized project teams aimed at achieving a significant and diversified set of performances (e.g. safety, environment, costs, management, etc.).

The environmental issues that arise from the development and operation of airport infrastructure relate to noise, air quality, carbon and greenhouse gas emission, adaptation to climate change, 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.

IV Research aim and objectives

The main objective of the research is to identify environmental issues related to the operation and development of airport infrastructure that allows to define the evaluation criteria of design and technological strategies for the impacts minimisation and/or reduction. The final objective of the research is to define an evaluation system that links the sustainability requirements with their performance levels and with the design and technological strategies for the reduction or elimination of the environmental impacts.

V Research 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 operation and project strategies related to the green building design and the aviation industry. The analysis has been carried out 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 environmental issues related to the airport infrastructure development and operation;
- Define how they can act as a constraint to airport growth;

- Examine the infrastructural design, technological, operational and business practices required to minimise their impact;
- Indicate architectural and technological strategies for reducing or eliminating those impacts.

In-depth study has been focused on the definition of an airport-wide sustainability index. The study was underpinned by 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 is currently going on through survey, interviews, workshops, and focus groups in collaboration with the Centre for Aviation, Transport and the Environment (School of Science and the Environment, Manchester Metropolitan University, UK), involving academics, researchers, airport designers and consultants, and Airport Industry authorities such as Eurocontrol and ACI (Airport Council International).

The research is also enhanced by the proposal of a training module within the *Laboratorio di Progettazione Ambientale* (Environmental Design) in the Architecture Master Degree Programme at the Dipartimento di Architettura, Università degli Studi di Firenze. Students are asked to deal with the environmental issues related to the airport infrastructure using tools and methods developed through the doctoral research, providing the opportunity to evaluate their effectiveness in supporting the project design process and evaluate the most effective architectural and technological strategies for minimising airport impacts and improving design and technological performances.

Beyond the specific objectives of the research, these activities have raised awareness of the role of the researcher to create a dialogue between different disciplines and collaboration within experts from various fields in order to increase his/her expertise and - at a broader level - of the architect/technologist as effective interface between operators, stakeholders and experts involved in the project design process of airport infrastructure.

PART I

AIRPORT INFRASTRUCTURE

Chapter I.1 – Airports development scenario: implications on the design process

I.1.1_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 (Fig. I.1.1), (Airbus 2010 & 2013).

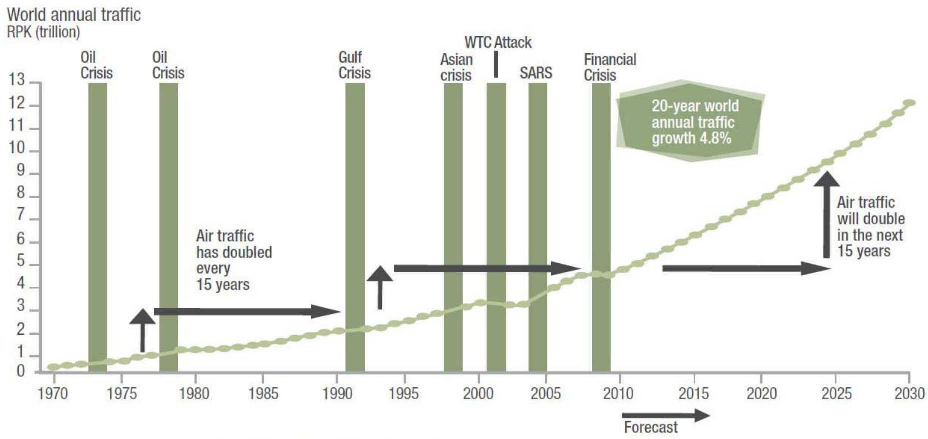

Figure I.1.1 – Air travel has proved to be resilient to external shocks. After several crises, air traffic is back to its potential [Source: AIRBUS (2010) Global Market Forecast 2011-2030 "Delivering the Future"]

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 (620ml), 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 (Fig. I.1.2) 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.

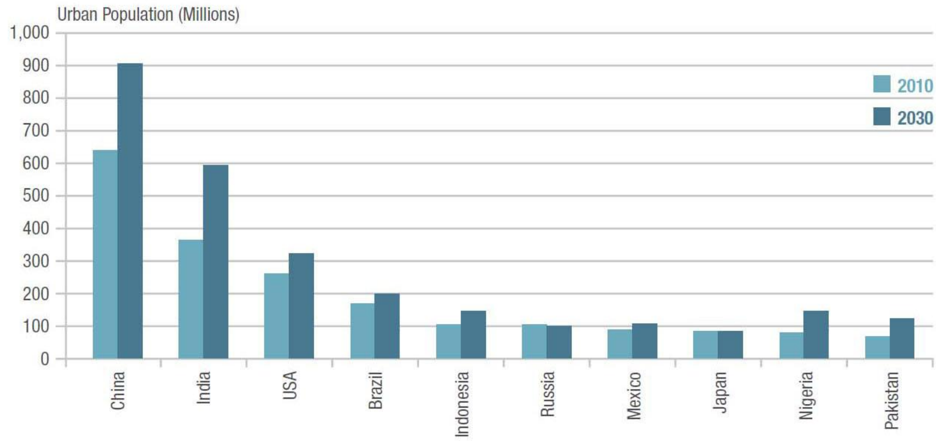

Figure I.1.2 – China, India and the USA – Countries with the largest number of people living in urban areas
[Source: AIRBUS (2010) Global Market Forecast 2011-2030 "Delivering the Future"]

European Commission's (EC) 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. These parts of the world are characterised by having poorly developed airport (and other) infrastructure so 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.

I.1.2 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 organization 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.
Despite the shift of air traffic flow towards the mega-hubs in emerging countries, the European aviation market will continue to expand the number of commercial flights will be increased from 9.4 million in 2011 to 18.6 million in 2050 (Eurocontrol, 2013).
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 and the difficulty of securing planning approval for new airport infrastructure development (Advisory Council for Aviation Research in Europe (ACARE), 2008). 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 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 (ACARE, 2010). 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, 2013a; EC, 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 (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).

I.1.3 Evolution and change of European regulation: *Towards 2050*

The cost of fuel and ticket prices, environmental awareness, restrictions on the use of fossil fuels, the problems related to operational and flight safety, planning and financing of infrastructure, standardization and innovation in the field of air transport, are some of the main challenges for the airports[1] (Eurocontrol, 2013a). They are associated with problems related to congestion and flight capacity constraints, instability in oil prices and concerns about climate change.

In airport planning the awareness of these factors cannot be disregard from the continuous search for the best solutions to achieve the expected performance. Europe, which faces competition with North America and the emerging economies, can maintain high levels of competitiveness only through an increase in investments in the field of technology and research and efficient integration of policies for the management and development of the Member States. Plan and manage the development of a evolving sector such as aviation, linked to the variability of the economy, the continuous updating of technology and the growing traffic demand, will be possible by combining the advanced and innovative knowledge in the technology sector to a systematic system of regulations and standards.

In January 2001, the European Commission, through the so-called *Group of Personalities*, published he *European Aeronautics. A Vision for 2020* , a document signed by the representatives of the main European aerospace industries, that

[1] The list includes:

- Fuel & ticket prices
- Environmental awareness
- Restrictions on using fossil fuel for aviation
- Security issues
- Planning and understanding future travel needs
- Sovereignty and civil-military cooperation
- Liability issues
- The EC "market led" economic regulation model
- Financing the air transport system infrastructure
- Network de-fragmentation
- Resource scarcity management
- Changing role of the human operators in the ATM
- system
- Safety of complex ATM systems (safety culture,
- legal risks, system of systems)
- Lack of competent resources in the transition phase
- Standardization issues
- Innovation in ATM.

defines the guidelines for the European aviation industry, aircraft structure and engineering, and air traffic management. The *Vision for 2020* sets out five strategic areas for research and development: competitiveness (quality and affordability), environment (environmental sustainability), safety (flight safety), efficiency (operational capacity) and security (operational safety). Each area provides specific goals in order to set Europe towards high levels of competitiveness by harmonizing investment in the sector.

To specify and define an action plan to achieve these objectives, the Advisory Council for Aeronautics Research in Europe (ACARE) was established. ACARE is a body composed of stakeholders in the air transport sector. In 2002 and 2004 it set out the contents of the *Vision* through two versions of the Strategic Research Agenda (SRA).

The first edition (SRA-1) identified the objectives, contributions and solutions to the five major problems of aviation with the aim to provide a system of air transport more accessible, clean and safe. Those objectives are:

- competitiveness: offer products and services that are competitive at international level about efficient performance, quality and operational economy and cost effectiveness, to airlines, passengers and customers;
- environment: be sensitive and attentive to the needs of society, reducing the environmental impact of operations management, maintenance, production and disposal of aircraft and associated systems;
- safety: reduce the accident rate compared to a steady increase in the number of flights, thus supporting the confidence of the airline companies and passengers;
- efficiency of the air transport system: ensure high levels of efficiency of the entire air transport system, through international competitiveness, increasing the capacity, optimization of time and cost and passenger comfort, keeping control the critical issues related to delays and congestion of the infrastructure;
- security: increase the level of operational safety compared to the terrorism threats, developing appropriate measures within a diversified and complex system.

The procedures aimed at achieving these objectives are related to the research in the field of infrastructure and technology, through models and processes certified and highly qualified, establishing a network of skills linking suppliers at various levels and a system of education and refresher courses for operators which ensure the synergy of the Member States in the pursuit of common goals and standards.
The second edition (SRA-2) is based on the new *High Level Target Concepts* (HLTC)[2] and identifies technologies and solutions that must be developed and

[2] The "high level objectives" are classified into 5 categories:

increased for the protection of the environment, the reduction of time and costs and to ensure efficiency, safety and the possibility of modal choice by the passengers.

The objectives of the SRAs have been carried out in Europe through the European Research Framework Programmes which include research in aeronautics and air transport, the Clean Sky Joint Technology Initiative and the Single European Sky Air Traffic Managment Research (SESAR) Joint Undertaking.
Research in Europe, through the Seventh Framework Programme of the European Commission, has expressed the goal of developing pan-European transport systems safer, greener and more efficient that would benefit all citizens of the community and which would guarantee a high level of competitiveness of European industry.

Horizon 2020 through its Work Programmes, funds researchers and innovators and supports project across the cycle from research to innovation creating the opportunity to build international research teams of researchers from both industry and academia with a multidisciplinary background. Under the Work Programme *Smart, green and integrated transport*, the focus area *Mobility for Growth* sets research and innovation on smart infrastructure solutions as necessary to deploy innovative traffic management and information systems, advanced traveller services, efficient logistics, construction and maintenance technologies.

The European Commission communication COM (2011) 823 EU to the Parliament, Council, the European Economic and Social Committee to the Conference of the Regions *Airport policy in the European Union - addressing capacity and quality to promote growth, connectivity and sustainable mobility*, confronts this problem by proposing an European regulation scheme that could face three challenges: capacity, quality and environment. The main actions are aimed at the improvement of flight performance, the technology of modern aircraft systems, efficient traffic management. Actions can be arranged through the use of environmental standards even within the design, construction, operation, maintenance and decommissioning of the entire airport infrastructure.

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 (in function of

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- *highly customer-oriented Air Transport System;*
- *highly time-efficient Air Transport System;*
- *highly cost-efficient Air Transport System;*
- *ultra-green Air Transport System;*
- *ultra-secure Air Transport System.*

traffic capacity). Working in this way means that long-term planning of airport areas has to take into account environmental constraints (legal, community, lack of resources, etc.) and the relationship with the urban functions set up in proximity of airport areas.

With its leading knowledge and manufacturing capability, the European aviation industry is in a position to define and shape a sustainable future. […] Today and even more so tomorrow, a safe and efficient Air Transport System, led by innovative technology, will be a vital vector for our economy, our society and the cohesion of Europe and the world (EC, 2011). 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).

The largest airports in the world are located near to the biggest urban conurbations (where aviation costumers live). Originally they were built in open country sites but due to poor land use planning many now find themselves surrounding by domestic and industrial infrastructure which threaten their growth. The debate surrounding a third runway at Heathrow Airport provides a very real illustration of the concept of airport environmental capacity and calls into question the longer term sustainability of airports in their current form.

Architects has 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.

Chapter I.2 – The airport terminal design as research field of green performance evaluation

I.2.1 Factors influencing airport design

The need for expansion of airport infrastructure faces the environmental factors and urban plans, the availability of land and its ability to accept or allow infrastructure expansion, the availability of new air routes. These aspects are often real bottleneck with delays and risks to the realization of the plans if not carefully valued at the beginning stages of airport planning.
Airports have been designed as a function of two factors: the increased flow capacity associated with the introduction of a faster means of transport and the need for standardization imposed by international technical legislation for the interoperability between airports from different countries. In all the world the airport infrastructure design follows the same methodologies, standards and technical normative references strictly dependent on the functional and operational needs of the air transport.
A civil airport is composed of four main parts:

1. runway/s, taxiway/s and aircraft parking (airside)
2. passenger terminal with the area of access to the terminal and intermodal exchange (landside)
3. service buildings (e.g. police, offices, etc.)
4. buildings intended for operators for freight and ground services

Airport layout planning depend on: site topography and geology; wind load and direction, which must always be in relation to the take-off and landing direction; size and number of terminal building; ground transport system (road and railway main access); safety distance between runways and buildings .

I.2.1.1 Operational Capacity

The main aspect which characterises the airport conception is its operational capacity. This depends on the number of runway slots, terminal capacity or the capacity of the apron areas and it is strictly related to the airspace capacity (air traffic demand, available slots, etc.). The maximum number of passenger and flights is however limited by the ATM (air traffic management) system that serves the airport and more generally by the quality of management of the whole infrastructure system. All these factors are affected by environmental issues which can constraint both the capacity of an airport and the potential for future growth.
ACI defines six categories, referred to as Key Performance Areas (KPAs), which defines the main factors that influence airport infrastructure design and provide a set of performance measures (performance Indicators, PIs), (ACI, 2012). The opportunity to work with specific indicators, helps to better define the development strategies of the infrastructure, give priority to the most important aspects and issues which can have an impact on the definition of airport performances, assess (measure) the most efficient set of project and design

solutions. The core indicators which measure the overall airport activity and also affect other infrastructure performance are: number of passengers, origination and destination (O&D) passengers, aircraft movements, freight or mail loaded/unloaded, non-stop destinations. These indicators are the most important measures of the airport service related to the quality of air transportation, the financial health and the regional economic impact. These are considered the first drivers of an airport development and characterize the infrastructure features and possible future growth.

The airport Infrastructure operational capacity is function of: requisite airspace, number of runways, extent of taxiway, aprons development, airside facilities, number and size of terminals, landside facilities, ground access, land availability and compatibility (for future growth opportunity). All these aspects define the "saturation point" of the airport system which depends on: aircraft traffic infrastructure geometry and configuration; physical characteristics of the aircraft and type of operation; environmental conditions; visibility, wind, grip, noise abatement; procedures for the control of air traffic in the terminal; assistance to aircraft during take-off or approach, which forms the interface between the control traffic route (ACS) and the airport facilities; runway capacity which is the number of movements allowed by this in a well-defined time interval.

- **Airspace Design**

The Airspace Design - as defined by Eurocontrol – supports the development, coordination and implementation of airspace structure improvement proposals to optimise both en-route and terminal airspace in the European area, enhancing ATM capacity and flight efficiency in line with forecast demand. The objective of Airspace Design is to ensure an efficient, flexible and dynamic airspace structure that will accommodate future air traffic demand and meet the Single European Sky (SES) Performance requirements in terms of capacity and flight efficiency, in a cost-effective manner. Airspace design depend on international regulations and standards related to technical requirements, airspace utilization and route network availability, optimization of airport operations and performances, but it is also affected by fuel prices and the need to improve flight efficiency and reduce impacts on the environment.

- **Airfield configuration (number of runways, extent of taxiway, aprons development)**

The airfield configuration depends on runway and taxiway position. Their orientation and dimensions is affected by the type and size of aircraft, air traffic management procedures, natural and man-made constraints on and surrounding the airport, wind and weather conditions, and federal regulations and design standards (ACRP, 2009). The site planning is affected by airside constraints and functions which determine the navigable airspace:

- safe areas around the runways protect the airspace and approaches to each runway from hazards that could affect the safe and efficient operation of aircraft
- aircraft maneuvering and separations are affected by type, terminal configuration, number of gates, and configuration of the runways

- airport apron layout and the type of gate to use largely depend on the level of aircraft traffic that is to be accommodated, the terminal layout, and local airport conditions.

➢ **Number and size of terminals (airside and landside facilities)**

Terminal siting and design is affected by the existing and future airfield layout requirements, airport's role in the national and international air transportation network, applicable air traffic control system parameters, the traffic demand from the immediate region and neighboring communities, and regional and city transportation plans.

The terminal planning and design need to consider: airside and landside planning requirements, terminal apron planning, aircraft gate requirements, ground transport access. The primary elements to consider when dealing with the airside component of a terminal complex include the following: aircraft parking restrictions, aircraft maneuvering, aircraft parking, aircraft parking apron, apron service roads, ground service equipment, aircraft servicing, security and emergency response, environmental (fuel spillage, waste disposal), winter operations (aircraft deicing, apron snow removal). The primary elements to consider when dealing with the landside component of the terminal complex include the following: curbfront pedestrian facilities, curbfront vehicle lanes, parking, entry/exit roadways, commercial vehicle/transit staging areas, rail transit. The airport terminal is the connection between the ground access system (landside - airport roads, curb frontage, parking, ground transportation) and the aircraft (airside - aircraft gates and airside accessibility). It consists of a ground access interface, a system of components for the processing of passengers and their baggage, and an aircraft or flight interface. A variety of factors affects the terminal planning decisions: existing configuration and size of airport facilities, volume of airport traffic, airport service area, passenger characteristics, presence and proportions of domestic and international service, airline route and station characteristics, operating procedures and policies, aircraft fleet mix, extent of non-scheduled airline service (ACRP, 2009).

Airport passenger terminal design depends on the number of passenger and the levels of service (LOS) and facilities necessary to support the operational requirements. The LOS[3] define qualitative and quantitative parameters for each terminal component; they describe the service provided to airport travelers at various points within the airport terminal building. It often relates to the degree of congestion or crowding experienced by travelers at the passenger and baggage

[3] The LOS concept was adopted by Airport Authorities Coordinating Council (AACC), now Airports Council International (ACI), and International Air transport Association (IATA) and published as part of AACC/IATA's *Guidelines for Airport Capacity/Demand Management*. The IATA LOS definitions are:

A- Excellent LOS; condition of free flow; no delays; excellent level of comfort.

B- High LOS; condition of stable flow; very few delays; high level of comfort.

C- Good LOS; condition of stable flow; acceptable brief delays; good level of comfort.

D- Adequate LOS; condition of unstable flow; acceptable delays for short periods of time; adequate level of comfort.

E- Inadequate LOS; condition of unstable flow; unacceptable delays; inadequate level of comfort.

F- Unacceptable LOS; condition of cross flows; system breakdown and unacceptable delays; unacceptable level of comfort.

processing facilities in the terminal building. It may also be a measure of the amount of waiting or processing time, or the length of the queues or lines encountered by such travelers at these facilities.
The terminal layout must be functional and flexible in order to facilitate future building development and improvement in order to maintain the operational effectiveness which can be compromised by: unexpected changes in the profile or pattern of airline demand growth, pace of technological and building services innovation, introduction of new service or regulatory requirements, emergence of new business strategies.

- **Ground access transportation**

Ground access facilities represent the link between the airport and the surrounding region. The intermodal transport and its integration on the territory characterize the future development policies on the sustainable mobility and require a coordination on the part of local, regional and state governments from airport operators and public and private transportation providers. Increasingly, airport planners worldwide are seeing merit in encouraging the use of public transportation to access airports, in order to reduce road congestion and the amount of land required for the parking of private vehicles, and to facilitate travel for airport employees. Good connectivity between the airport terminal and the various public transportation modes is an essential component of this strategy.
At a regional scale the ground transportation planning has to take into account the projected future needs of airport users. Locally, the ground access planning must consider the design to accommodate the expected traffic growth and the connections between components of the airport facility.
Airports often become a point of convergence for many different modes of transportation including road, rail, and, in some cases, ferry. Increasingly, airport planners worldwide are seeing merit in encouraging the use of public transportation to access airports, in order to reduce road congestion and the amount of land required for the parking of private vehicles, and to facilitate travel for airport employees. Good connectivity between the airport terminal and the various public transportation modes is an essential component of this strategy.

- **Land availability and compatibility (for future growth opportunity)**

The assessment of airport development compatibility with surrounding land uses is one of the primary objectives of the infrastructure planning process. The land use analysis must be carried on a regional and local basis in order to identify impacts and constraints which could affect the future infrastructure development.
At the regional level, the main concern is the potential incompatibility with other planned transportation projects in the region. This can affects both the urban, social, economical development of the region and the risks related to the environmental, geomorphological and hydrogeological features of the site and its ecosystem. During the early stages of the airport infrastructure planning is essential to identify any potential incompatibility with the territory and consider the opportunity of a transport system integrated with the territory (roads, railway).
At the local level, environmental issues are associated with the community constraints arisen because of the increasing noise and pollutants emissions, safety

concerns and secondary development, such as hotels, rental car facilities, restaurants, gas stations, and off-airport parking.

I.2.1.2 Operational Efficiency

Airport operational efficiency depend on the infrastructure capacity and on the controller tools and processes supporting the air traffic management system. The first aim of this system is to monitor and control the volume of traffic demand and assure safety levels of the whole system.
In the “Vision 2020 report” the European Commission identify as objective of the European Air Transport a punctuality target of 99% of flights departing and arriving within 15 minutes of their timetable in all weather conditions (ACARE, 2008). To face this objective the Air Transport System has to work in different directions:

- Optimizing the use of existing ATM-Airspace capacity through the implementation of techniques which balance and organize traffic according to the capacity constraints and possibilities
- Removing the ATM-Airspace Capacity Barrier through the development of new automated systems, including more autonomous aircraft-based capabilities and/or more advanced, dependable ground-based systems in support to human operators
- Maximizing current airport performance by exploiting measures such as: enhanced operational concepts, supported by new decision-making or decision-support tools should ensure more efficient use of the airport infrastructure, even in adverse weather conditions
- Developing new technologies in order to process passengers and luggage ensuring the required levels of security even in anticipation of increasing number of passenger.

I.2.1.3 Operational Costs

There are two main performance areas which define airport operational costs (ACI, 2012):

- Productivity/Efficiency indicators which measure the resources used to produce a certain volume of activity. They track and integrate output on a non-cost basis (i.e. passengers per employee, aircraft movements per employee, aircraft movements per gate) and output on a cost basis (i.e. total cost per passenger, total cost per movement, operating cost per passenger, operating cost per movement)
- Financial/Commercial indicators which are related to airport charges, airport financial strength and sustainability, and the performance of individual commercial functions. They are the most widely used and are closely tracked by airports, airlines, and regulators: Aeronautical Revenue per Passenger, Aeronautical Revenue per Movement, Non-Aeronautical Operating Revenue as Percent of Total Operating Revenue, Non-Aeronautical Operating Revenue per Passenger, Debt Service as Percentage of Operating Revenue, Long-Term Debt per Passenger, Debt to EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization) Ratio, EBITDA per Passenger.

Over the long-term, the indicator which will have a greater impact on the overall operational costs is the fuel price. It already represent the main part of air transport operating costs and can negatively affect profitability and return of investment of the airlines and airport business planning.

I.2.1.4 Security

Transport security is the most important source of concern for airport operational and design strategies. Security checks prevent from dramatic events that could have detrimental effect on air transport growth, but also affect the travelling convenience increasing airport transit time. This reduce the willingness of the passengers to travel and increase airport operating costs by USD 0.5 per passenger - security amounts around 35% of airport operating costs (Eurocontrol, 2009).
The primary areas of the terminal complex which requires a detailed security plan are:

- Vehicle and pedestrian gates and portals, planning for vehicle checkpoints, apron areas (airside)
- Terminal lobby issues, employee, passengers and baggage screening (terminal)
- Access roadway and terminal curbside, multi-modal and multi-terminal connections (landside)

Besides airport security, navigation and ATM infrastructure is concerned with protecting the system from interference and with providing secure means to maintain control of aircraft in transit and airborne security secure aircraft operations and prevent unauthorized staff and unplanned trajectories.

I.2.1.5 Safety

Safety concerns the safe operation of a planned and managed system whilst security defends that operation from the deliberate actions of the terrorist or criminal. The overall efficiency and environmental performance of the global air transport system is assured by the continuous safety enhancements.
The safety of travelling by air is an absolute pre-requisite for air transport. Air transport is recognized as a very safe mode of transportation. However, society has an increasing sensitivity to risk, which exerts more pressure on safety considerations (Eurocontrol, 2009).
Safety indicators (e.g. runway accidents, runway incursions, bird strikes) are used to track airfield safety issues as well as safety issues involving other portions of the airport, including roadways, and general employee safety (ACI,2012).
Within ACARE, the objective of the "safety challenge" refers to the 80% reduction of accident rate, with particular focus on drastic diminution of human error, in the Air Transport System of the years 2020 considering the three fold air traffic increase (ACARE, 2008). The recommended Research & Development activities are aimed to reduce drastically:

- the three major categories of accidents: approach/landing, Controlled Flight into Terrain (CFIT) and loss of control.
- the main causes of accident, as resulted from the current statistics and reflection on their evolution in relation with the Air Transport vision:

atmospheric hazards, failure to maintain safe separation between aircraft in flight, collision risk on ground
- the occurrence of human error and its consequences.

I.2.1.6 Customer service expectations

Airport infrastructure and terminals, in particular, have undergone an evolution which develop the service quality definition from having a primary focus on facilities and operations to having a strong customer service focus in an increasingly competitive environment. The terminal building has to accommodate facilities for the processing of passengers and spaces where travelers can easly and quikly move but also areas where they may be expected to spend significant periods of time (food courts, retail nodes, etc.). Service quality indicators focus both on airport level of service and how they are perceived by the passengers and on service delivery objective measures (i.e. practical hourly capacity, gate departure delay, taxi departure delay, customer satisfaction, baggage delivery time, security clearing time, border control clearing time, check-in to gate time.

The passenger convenience is related to three primary factors: distance a passenger must walk and the associated ease or difficulty involved in traversing this distance; passenger's feelings about the terminal facilities and ambiance; time associated with moving through the terminal (ACRP, 2009).

PART II

Environmental Sustainability Definition and Evaluation

Chapter II.3 – Environmental sustainability evaluation

II.3.1 Principles of sustainable design

II.3.1.1 Defining sustainability

Sustainable and green design are about defining new values and setting higher environmental performance standards. But this is also about rethinking design process and properly evaluate design and technological strategies since the early stage of the project design process. The definition of notions such as "sustainable" and "green" and the distinctions between these two concepts and how they affect the building design is critical.

The notion of 'sustainable development' has emerged as a guide to all human activities (World Commission on Environment and Development (WCED), 1987) and its pervading claim in the international debate has reached maturity as a result of the acceptance of the IPCC predictions on climate change (Reed & Wilkinson, 2009) resulting from economic reports such as the Stern Report to the government in the United Kingdom (Stern, 2005). The awareness of the climate changing conditions and their impact on the built environment, lead to the formulation of integrated systems of actions that reduce greenhouse gas emissions while adopting sustainability practices.
Sustainable development represents a key goal for international policy makers (Singh *et al*., 2012) as it indicates a comprehensive (holistic) approach to global, national and local issues and implies not only the ever changing conditions that defines sustainability, but also the way we approach it based on the different magnitude of those issues and the evolution of the environmental, social, cultural and economic conditions. This approach is the result of two main factors (Gibbert, 2002):

- "the increasing precision in the quantification and attribution of the causes of global environmental degradation and resource depletion and
- the realisation that the extent and urgency of global environment problems will require a concerted and integrated effort, internationally, and across social, environmental and economic sectors".

Based on these considerations, it is clear that the sustainable development can be assured only through a long-term life cycle thinking (Cole, 2013).
Young described sustainability as a three-legged stool, with a leg each representing ecosystem, economy and society, linked together to assure the stability of the system (1997). Sustainability is a combination of the individual and collective actions to sustain the environment as well as improve the economy and satisfy societal needs (Godfaurd *et al*., 2005; Hwang & Tan, 2012); an approach which Elkington in 1994 referred to as 'Triple Bottom Line' (TBL) where the three 'pillars of sustainability are associated to People, Planet and Profit (3Ps).

II.3.1.2 From sustainable development to green design

The different dimensions and the various issues of sustainability have to be integrated in the building project both as a single object and a system of interrelation with the surroundings (Mateus & Bragança, 2011). Thus, "the rational use of natural resources and appropriate management of the building stock will contribute to saving scarce resources, reducing energy consumption, and improving environmental quality" (Godfaurd *et al*., 2005).
Moreover in the Architecture, Engineering & Construction (AEC) sector the accomplishment of sustainability concepts has to be pursued not only during the planning and design process, but also in the construction stage (Hill & Bowen, 1997; Ding, 2005). Du Plessis describes sustainable construction as a "subset of sustainable development" (1999). It has been defined in 1994 by the Conseil International du Batiment (CIB) as "creating and operating a healthy built environment based on resource efficiency and ecological design" and articulated in seven principles which would inform decision making during each phase of the design and construction process, continuing throughout the building's whole life cycle (Kibert, 1994):

1. Reduce resource consumption (reduce)
2. Reuse resources (reuse)
3. Use recyclable resources (recycle)
4. Protect nature (nature)
5. Eliminate toxics (toxics)
6. Apply life-cycle costing (economics)
7. Focus on quality (quality).

The principles of sustainable construction are relevant across the entire life cycle of construction, from planning to deconstruction and disposal. The seven principles should be the valid basis when considering the resources needed to create and operate the built environment during its entire life cycle (Kibert, 2008; Abduh *et al*., 2014). As a consequence of these statements, the aim of sustainable design is to reduce or eliminate negative impacts to the natural environment, while maximizing the quality of the built environment (Buck, 2004; McLennan, 2004).

'Green' emphasises design and technological strategies (e.g. applying solar energy, day-lighting and natural ventilation, waste treatment for recycling) which comply with the sustainability requirements (Wang *et al*., 2005; ALwaer & Clements-Croome, 2010). Therefore green is generally associate to buildings that are designed, constructed, and operated to boost environmental, economic, health, and productivity performance over conventional building (United States Green Building Council (USGBC), 2003). Green building is associate to the practice of increasing the efficiency with which buildings and their sites use resources (e.g. energy, water, materials) and reducing impacts on human health and the environment during the whole building life cycle (Cassidy, 2003; Kats, 2003; Ries *et al*., 2006; Castro-Lacouture *et al*., 2009), resulting also in economic benefits savings in operation and maintenance costs (Ross *et al*., 2006).
ASTM Standard E2114–04 (2004) defines green building as 'a building that provides the specified building performance requirements while minimising

disturbance to and improving the functioning of local, regional, and global ecosystems both during and after its construction and specified service life'. As stated by Burnett, green building emphasises performance requirements of sustainable development (2007).
The concept of green building has developed from a system of design and technological strategies aimed at minimising environmental impact to a life cycle and holistic approach associated to "healthy, safe and productive built environment and the evaluation of the benefits and costs of the project, improving the quality of buildings and services and promote social cohesiveness and using technology and expert knowledge to seek project efficiency and effectiveness" (Zainul Abidin & Pasquire, 2005). Therefore, even if there is no a single definition for green building, it has become common to refer to it as a synonym of sustainable design, sustainable construction and other associated expressions (Robichaud & Anantatmula, 2011).

II.3.1.3 Sustainability assessment

In pursuing sustainability in the AEC sector, 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). Therefore not only the nature of the built environment is changed, but also the method of designing and constructing, leading to a new 'paradigm of building' (Mateus & Bragança, 2011) characterised by the selection of experts in sustainable building as team member collaborating with the stakeholders with the common focus on global building performance supported by a life cycle approach (Kibert, 2005).

The attention to the role of team members and stakeholders and their role during the whole building life cycle has raised the need of defining the rules and measures to evaluate sustainability to help decision-makers decide what strategy should take and assess the associated performance levels (Pope *et al*., 2004).

Sustainable assessment has primarily evolved in connection to the Environmental Impact Assessment (EIA) and the Strategic 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. The contribution of SEA is therefore take those effects into account in the early stages of planning. A series of tools has consequently been developed since the early 90's to address the environmental implications of decisions made at this level (Therivel & Partidario, 1996; Partidario, 1999; Dalal-Clayton and Sadler, 2002; Dovers, 2002).

Governments and practitioners are increasingly adopting voluntary initiatives and frameworks as a policy tool and evaluation guides to promote sustainability achievement and improve environmental performance in the construction industry (Lee *at al*., 2002; Sinou &Kyvelou, 2006; Cheng et al., 2008; Ding, 2008; Poston *et al*., 2010). An effective framework for integrating sustainable development and assessing building environmental performance in the project design process is represented by rating systems. They are applied as design tools for the definition of sustainability priorities and goals, the development of appropriate strategies and the measurement of performances to inform the decision-making process (Crawley and Aho, 1999; Devuyst, 2000; Cole, 2003; Cam & Ong, 2005). With regard to the latter aspect, it is essential to notice the significance of the environmental performance measure as an essential prerequisite to the assessment of sustainable development (Mitchell, 1996). A problem has emerged in the definition of widely recognised quality standards due to the lack of consensus among the actors in the building sectors associating different metrics and values to the building assessment performance (Cole, 1998). Nevertheless assessment systems are increasingly adopted worldwide and developing from certification trend to current practice (Berardi, 2012).

II.3.2 Green building rating systems

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 systems' development and evolution has raised the need to improve the standardisation of issues that pertain to environmental building at both European and international level (Haapio & Viitaniemi, 2008; Malmqvist, 2008; Mateus & Bragança, 2011; Alyami & Rezgui, 2012; Berardi, 2012) with the aim to establish common frameworks of definition the system boundaries, functional units, environmental indicators, presentation of results, *etc*. (Malmqvist, 2008).

The International Organization for Standardization (ISO) and the European Committee for Standardization (CEN) have been active in providing respectively frameworks and recommendations on sustainability in building construction (ISO, 2006a; 2006b; 2008) and definitions for the standardised requirements for the environmental assessment of buildings and framework for assessment of environmental performance of buildings within CEN/TC 350 (CEN, 2005; 2007).

II.3.2.1 Characteristics

Rating tools attempt to optimize 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).

The major components of a rating systems are (Cole, 2013):

- the structure, a fixed set of performance criteria organised in a certain number of categories which generally represent different sustainability issues (e.g. energy, water, health and wellbeing);
- the scoring, possible points or credits that can be earned by meeting a given level of performance associated to each performance issue;
- the output, a means (e.g. a chart) of showing the overall score.

II.3.2.2 Diffusion

A number of tools using sustainability indicators have been developed in the last two decades. International Green Building rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), CASBEE (Comprehensive Assessment System for Built Environment Efficiency), GBTool (Green Building Tool), Protocollo ITACA (Istituto per l'Innovazione e Trasparenza degli Appalti e la Compatibilità Ambientale), and others have been used as an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes (Cole, 2003; Forsberg & von Malmborg, 2004; Ding, 2008; Haapio & Viitaniemi, 2008; Reed *et al*., 2009; Robichaud & Anantatmula, 2011; Berardi, 2012).

A literature review was conducted to support the development of the *GrADE* evaluation system (framework), and to ensure that existing pertinent work was included in this research. The research team reviewed and evaluated current sustainability practice resources, sustainability development guidelines, sustainability performance metrics, and sustainability rating systems and certification programs used by the Architecture/Engineering/Construction (AEC) industry as well as by the airport-industry organizations.
For the purpose of this research, five distinct types of sustainability rating systems have been considered:

- ‘New Construction. Non-domestic Buildings’, Technical Manual 2014, Building Research Establishment’s Environmental Assessment Method (BREEAM)
- ‘Building Design and Construction’, version 4, 2015, Leadership in Energy and Environmental Design (LEED)
- ‘Sustainable Airport Manual’, version 3.2, 2014, Chicago Department of Aviation (CDA)
- ‘Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects’, version 5.0, 2010, Los Angeles World Airport (LAWA)
- ‘Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options’, report 119, 2014, Airport Cooperative Research Program (ACRP)

Besides being the most diffuse rating systems, BREEAM and LEED are currently applied to certify airport terminal building in different countries (e.g. San Francisco Airport's terminal 2, New Delhi Airport terminal 3, Heathrow Airport terminal 2).
The CDA's and LAWA's manuals represent the first attempt to apply and customize the existing rating building (in this specific case, they both relate to the LEED New Construction technical manual) to the specific characteristics of airport infrastructure planning and design.
The ACRP prororype, published on December 2014, is the result of five-year-study to develop a specific airport rating system. It represents the only case of a research involving a wide range of operators, professionals and academics who work in the airport industry sector of the United States. Similarly to this proposal, the results presented in this research are the first system of evaluation of airport environmental sustainability proposed in Europe. In fact, only major European airports have developed their own environmental policies based on the specific environmental issues of the airport and on the objective of their strategic planning and future development. However those documents are not based on a structured framework nor they refer to a specific and established evaluation system.

II.3.2.3 BREEAM

Building Research Establishment's Environmental Assessment Method (BREEAM) is the world's longest established and most widely used environmental assessment method for buildings (www.breglobal.com). It was launched in 1990 by the Building Research Establishment (BRE) which is a private organisation that provide expert, impartial research, knowledge and advice for the built environment sector (www.bre.co.uk).

<u>Fields of application</u>
BREEAM is a flexible system as it covers different types of buildings, namely offices, homes, industrial units, retail units, courts, healthcare units, prisons, multi-residential, and schools, with specific reference to design, construction and operation and maintenance activities according to the versions (schemes) for new or existing buildings, refurbishment projects and large developments. For the purpose of this research, the BREEAM UK Technical Manual "New Construction, Non-domestic Buildings" is considered and further analysed.

<u>Structure</u>
BREEAM is recognised as the first green buildings assessment method (Ding, 2008; Kibert, 2008; Haapio & Viitaniemi, 2008a; Mao *et al*., 2009). The aim of the BREEAM method is to provide a guidance on ways of improving environmental performance of buildings while promoting internal healthy and comfortable environment for occupants (Baldwin *et al*., 1998). The main objective is to evaluate building's specification, design, construction and use through a set of recognised measure of performance - developed through the national consultative process - covering a range of criteria (requirements) split in ten categories (Table II.3.1). Common metrics enables comparison on certain strategies and sharing of nest practice and knowledge. This stimulate the demand

for sustainable buildings and challenge the market for more innovative solution. For the purpose of this research, BREEAM "New Construction, Non-domestic Buildings" (2014) is further analysed.

Table II.3.1_BREEAM New Construction (Non-domestic Buildings) technical manual's categories and criteria

CATEGORY	CRITERIA
Management	Project brief and design
	Life cycle cost and service life planning
	Responsible construction practices
	Commissioning and handover
	Aftercare
Health & Wellbeing	Visual comfort
	Indoor air quality
	Safe containment in laboratories
	Thermal comfort
	Acoustic performance
	Safety and security
Energy	Reduction of energy use and carbon emissions
	Energy monitoring
	External lighting
	Low carbon design
	Energy efficient cold storage
	Energy efficient transportation systems
	Energy efficient equipment
	Drying space
Transport	Public transport accessibility
	Proximity to amenities
	Cyclist facilities
	Maximum car parking capacity
	Travel plan
Water	Water consumption
	Water monitoring
	Water leak detection
	Water efficient equipment
Materials	Life cycle impacts
	Hard landscaping and boundary protection
	Responsible sourcing of materials
	Insulation
	Designing for durability and resilience
	Material efficiency
Waste	Construction waste management
	Recycled aggregates
	Operational waste
	Speculative floor and ceiling finishes
	Adaptation to climate change
	Functional adaptability
Land use and Ecology	Site selection
	Ecological value of site and protection of ecological features
	Minimising impact on existing site ecology

	Enhancing site ecology
	Long term impact on biodiversity
Pollution	Impact of refrigerants
	NOx emissions
	Surface water run-off
	Reduction of night time light pollution
	Reduction of noise pollution
Innovation	Innovation

[Source: BREEAM UK Technical Manual SD5076: 3.0 – 2014, New Construction, Non-domestic Buildings, www.breeam.com]

<u>Point allocation</u>

The assessment is based on pre-weighted credits (points) allocated to predictable practices and performance levels which are compared to specified standards and key issues of each criteria. The credits are added to produce the final score on a scale as shown in Table II.3.2.

Table II.3.2_BREEAM rating benchmarks

RATING	SCORE (%)	PERFORMANCE EQUIVALENT
Unclassified	<30	Under the standard
Pass	>= 30%	Standard good practice
Good	>= 45%	Intermediate good practice
Very Good	>= 55%	Advanced good practice
Excellent	>= 70%	Best practice
Outstanding	>=85%	Innovator

[Source: www.breeam.com]

In order to achieve the minimum rating level, BREEAM set – beside minimum overall percentage score - minimum standards of performance in key areas in accordance with the national and international compulsory regulations. Based on this and on the general structure of the criteria, each category has a different environmental weight (Fig. II.3.1).

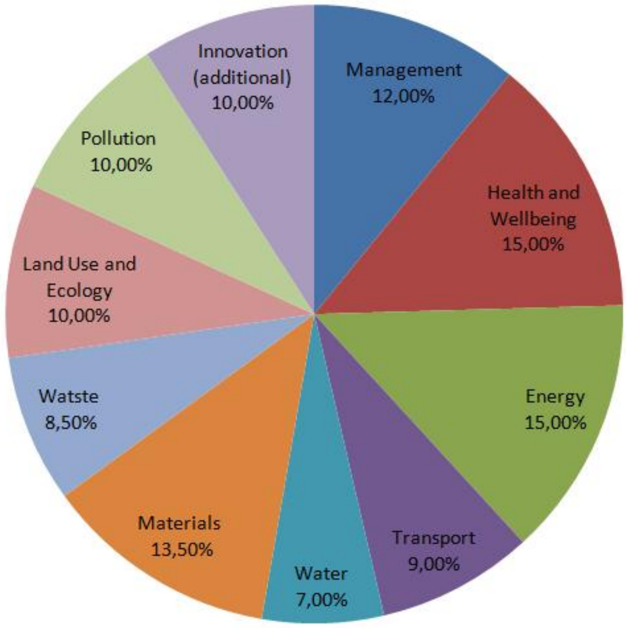


Figure II.3.1_BREEAM categories' weighting [Source: www.breeam.com]

II.3.2.4 LEED

As the BREEAM, the Leadership in Energy and Environmental Design (LEED) rating system is a volountary certification programme developed through a consensus process involving key stakeholders by the United States Green Building Council (USGBC). The USGBC is a private organisation founded in 1993 that promotes sustainability in building design, construction, operations and maintenance (www.usgbc.org).

<u>Fields of application</u>
The first LEED rating system was launched in 1998 and later developed in a number of manuals covering different building typologies and components: schools, healthcare units, retail units, core and shell, commercial and retail interiors, homes and neighbourhood develppment.

<u>Structure</u>
The LEED application and certification is based on a system of credits (requirements). There are two typologies of requirements: the prerequisite, which indicates strategies which are considered compulsory for the assessment of the final score; and the credits, which are associated with a different number of points based on the level of performance accomplished regarding the category they belong to. For the purpose of this research, LEED v4 "Building Design and Construction – New Construction" (2015) is further analysed. The system is divided in eight categories which include different number of requirements (Table

II.3.3) with the exception of the credit “Integrative Process” that doesn’t belong to any category.

Table II.3.3_LEED Building Design and Construction – New Construction manual’s categories and criteria

CATEGORY	CRITERIA
Location and Transportation	Credit: LEED for Neighborhood Development Location
	Credit: Sensitive Land Protection
	Credit: High-Priority Site
	Credit: Surrounding Density and Diverse Uses
	Credit: Access to Quality Transit
	Credit: Bicycle Facilities
	Credit: Reduced Parking Footprint
	Credit: Green Vehicles
Sustainable Sites	Prerequisite: Construction Activity Pollution Prevention
	Credit: Site Assessment
	Credit: Site Development—Protect or Restore Habitat
	Credit: Open Space
	Credit: Rainwater Management
	Credit: Heat Island Reduction
	Credit: Light Pollution Reduction
Water Efficiency	Prerequisite: Outdoor Water Use Reduction
	Prerequisite: Indoor Water Use Reduction
	Prerequisite: Building-Level Water Metering
	Credit: Outdoor Water Use Reduction
	Credit: Indoor Water Use Reduction
	Credit: Cooling Tower Water Use
	Credit: Water Metering
Energy and Atmosphere	Prerequisite: Fundamental Commissioning and Verification
	Prerequisite: Minimum Energy Performance
	Prerequisite: Building-Level Energy Metering
	Prerequisite: Fundamental Refrigerant Management
	Credit: Enhanced Commissioning
	Credit: Optimize Energy Performance
	Credit: Advanced Energy Metering
	Credit: Demand Response
	Credit: Renewable Energy Production
	Credit: Enhanced Refrigerant Management
	Credit: Green Power and Carbon Offsets
Materials and Resources	Prerequisite: Storage and Collection of Recyclables
	Prerequisite: Construction and Demolition Waste Management Planning
	Credit: Building Life-Cycle Impact Reduction
	Credit: Building Product Disclosure and Optimization—Environmental Product

	Declarations
	Credit: Building Product Disclosure and Optimization – Sourcing of Raw Materials
	Credit: Building Product Disclosure and Optimization – Material Ingredients
	Credit: Construction and Demolition Waste Management
Indoor Environmental Quality	Prerequisite: Minimum Indoor Air Quality Performance
	Prerequisite: Environmental Tobacco Smoke Control
	Credit: Enhanced Indoor Air Quality Strategies
	Credit: Low-Emitting Materials
	Credit: Construction Indoor Air Quality Management Plan
	Credit: Indoor Air Quality Assessment
	Credit: Thermal Comfort
	Credit: Interior Lighting
	Credit: Daylight
	Credit: Quality Views
	Credit: Acoustic Performance
Innovation	Credit: Innovation
	Credit: LEED Accredited Professional
Regional Priority	Credit: Regional priority

[Source: LEED v4 for Building Design and Construction, www.usgbc.org/leed]

Point allocation

The credit weighting process is based on the environmental impact categories of the Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) developed by the United States Environmental Protection Agency's and the National Institute of Standards and Technology's (NIST) environmental weighting scheme. Differently from the BREEAM rating score – where the weight of each category is considered beside the point allocated to the single requirement – the LEED level of accreditation (Table II.3.4) is based on a simple additive approach where the sum of total point/points awarded and the compliance with all the prerequisite are considered.

Table II.3.4_LEED rating benchmarks

RATING	SCORE
Certified	<40
Silver	40-49
Gold	60-79
Platinum	80-110

[Source: www.usgbc.org/leed]

The critical aspect of this system is that there is no weighting factors enabling the comparison between each category. Based on this and on the general structure of the criteria, the environmental weight of each category is based on the number of requirements and the total achievable points (Fig. II.3.2).

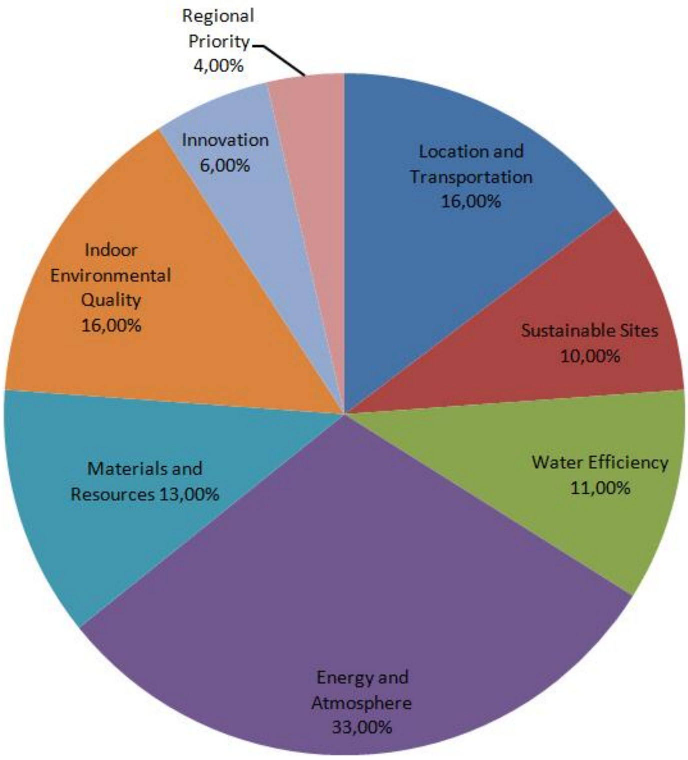


Figure II.3.2_LEED categories' points allocation [Source: www.breeam.com]

II.3.2.5 Final considerations

The rating systems, which initially represented only a tool for analysis and recognition of the environmental performance of green buildings, today are evolving into systems that combine the certification objective with that of the real performance management during the design process, providing a structured platform for the definition of the green project requirements and the performance measures to guide the sustainable design (AlWaer *et al.*, 2007; Ali & Al Nsairat, 2009; Biswas & Wang, 2009; Malmqvist *et al.*, 2011). But these programmes have mainly focused in particular upon the design of the individual building and does not consider the whole system of constraints and impacts which specifically affects the airport development as an integrated infrastructure. Evidence suggests that in terms of sustaining the future growth and development of an airport, environmental impacts that give rise to capacity constraints and refusal of planning approval are not only those associated with the energy efficiency of buildings, but rather other environmental impacts associated with the airports operation such as the disturbance caused to local residents from aircraft noise, local air quality, that is adversely affected by air and ground transport traffic *etc*.

II.3.3_Green Airport rating systems

The common certification systems such as BREEAM and LEED are focused on building with a little concern on the surrounding areas. But the individual buildings that comprise a major part of the airport infrastructure are not, on their own, the critical elements that determine the longer term sustainability of the site. Sustainability programmes and initiatives are being implemented by airport operators (Carlini, 2013) as part of their development strategies to meet economic, social and environmental benefits. In the United States, there are three examples of these programmes that have been developed as airport-related rating system: the *Sustainable Airport Manual* and the *Sustainable Airport Planning, Design and Construction Guidelines* implemented from LEED by the Chicago Department of Aviation (CDA) and the Los Angeles World Airports (LAWA), respectively; and the *Prototype Airport Sustainability Rating System*, developed by the Airport Cooperative Research Programme (ACRP).
The purpose of this paragraph is to analyse those programmes in order to identify airport-specific sustainable design and technological strategies that can inform the the early stages of planning and design decision-making process.

II.3.3.1 *Sustainable Airport Manual*, Chicago Department of Aviation

The Chicago Department of Aviation is the administrator of Chicago's two major airports, O'Hare and Midway International Airports. It introduced its first *Sustainable Design Manual* (SDM) in 2003 to serve as a guidance and sustainability benchmark during the modernization of Chicago O'Hare International Airport under the *O'Hare Modernisation Programme*. The SDM was the first sustainable guidelines for airport design and construction at a national and international level. It was based on the 2002 LEED *New Construction (version 2.1)* manual. Later it has been updated on the LEED *New Construction (version 3)* manual of 2009 and implemented in order to incorporate sustainable initiatives for airport planning, operations and maintenance, and concessions and tenants. Its name also changed in *Sustainable Airport Manual* (SAM). Further upgrades have been made during the last years. For the purpose of this research the latest version 3.2 of 2014 has been considered.

<u>Structure</u>
The SAM is composed of six chapters:

1. *Administrative Procedures*, integrates sustainable administrative activities with planning, design, construction, maintenance and operations;
2. *Planning*, provides policy guidance checklists and example establishing the framework for integration of sustainability into airport plans;
3. *Design/Construction*, sets the strategies for the sustainable design and construction of airside, landside and buildings;
4. *Operation/maintenance*, focuses on training, monitoring, reporting activities;

5. *Concessions/Tenants,* includes all terminal concessionaire, and landside and airside tenant facilities.

The chapter *Design/Construction* is further analysed for the purpose of this research, with the esclusion of *Construction* practices. This chapter includes seven categories (Table II.3.5) similar to those of the LEED rating system.

Table II.3.5_SAM categories and criteria

CATEGORY	CRITERIA
Sustainable Sites	Construction Activity Pollution Prevention
	Adopt CDA Best Management Practices
	Brownfield Redevelopment
	Alternative Transportation
	Stormwater Design
	Landscape and Exterior Design to Reduce Heat Islands
	Light Pollution Reduction
Water Efficiency	Water Use Reduction: 20% Reduction
	Water Use Reduction: 30%-40% Reduction
	Water Efficient Landscaping
	Innovative Wastewater Technologies
Energy and Atmosphere	Fundamental Building Systems Commissioning
	Minimum Energy Performance
	Fundamental Refrigerant Management
	Optimize Energy Performance
	On-Site Renewable Energy
	Enhanced Commissioning
	Enhanced Refrigerant Management
	Measurement and Verification
	Green Power
Materials and Resources	Storage and Collection of Recyclables
	Building and Infrastructure Reuse
	Construction Waste Management
	Balanced Earthwork
	Aggregate Reuse
	Material Reuse
	Recycled Content
	Local/Regional Material
	Rapidly Renewable Materials
	Certified Wood
	Furniture and Equipment
	Equipment Salvage and Reuse
Indoor Environmental Quality	Minimum Indoor Air Quality (IAQ) Performance
	Environmental Tobacco Smoke (ETS) Control
	Outdoor Air Delivery Monitoring Increased
	Increased Ventilation
	Construction IAQ Management Plan
	Low-Emitting Materials
	Indoor Chemical and Pollutant Source Contro
	Controllability of Systems
	Thermal Comfor

	Daylight and Views
	Noise Transmission
Innovation	Innovation in Design & Construction
	Menu Items
	LEED Accredited Professiona
	LEED Certified Project
Regional Priority	Regional priority

[Source: Chicago Department of Aviation, Sustainable Airport Manual – version 3.2, 2014; www.flychicago.com]

<u>Point allocation</u>

The SAM's *Design/Construction* rating weight is based on the *Green Airpolane Certification*, a point system established to designate achievement levels. It defines five tiers thresholds for each project type (Fig. II.3.6).

DC GREEN AIRPLANE RATING SYSTEM					
Green Airplanes	Civil-Airside	Civil-Landside	Occupied Buildings	Unoccupied Buildings	Renovations/ Remodeling
Prerequisites	6	6	13	11	8
✈	4-19	4-19	4-41	4-33	4-15
✈✈	20-24	20-24	42-51	34-42	16-19
✈✈✈	25-29	25-30	52-62	43-50	20-23
✈✈✈✈	30-39	31-40	63-83	51-68	24-31
✈✈✈✈✈	40-55	41-57	84-116	69-95	32-45
MAXIMUM	**55**	**57**	**116**	**95**	**45**

Figure II.3.6_SAM Design/Construction Green Airplan Rating System. The certification from two to five Green Airplanes fits LEED accreditation Certified, Silver, Gold, Platinum, respectively. [Source: Chicago Department of Aviation, Sustainable Airport Manual – version 3.2, 2014; www.flychicago.com]

As in LEED, each criteria could be a prerequisite or is associated to a variable number of points. Another similarity is that there are no weighting factors enabling the comparison between each category. The environmental weight of each category is based on the number of requirements and the total achievable points (Fig. II.3.3). But differently from LEED, a different threshold is assigned to each project type. It has been noticed that for each category the maximum number of possible points allocated is always referred to the *Occupied Building* typology.

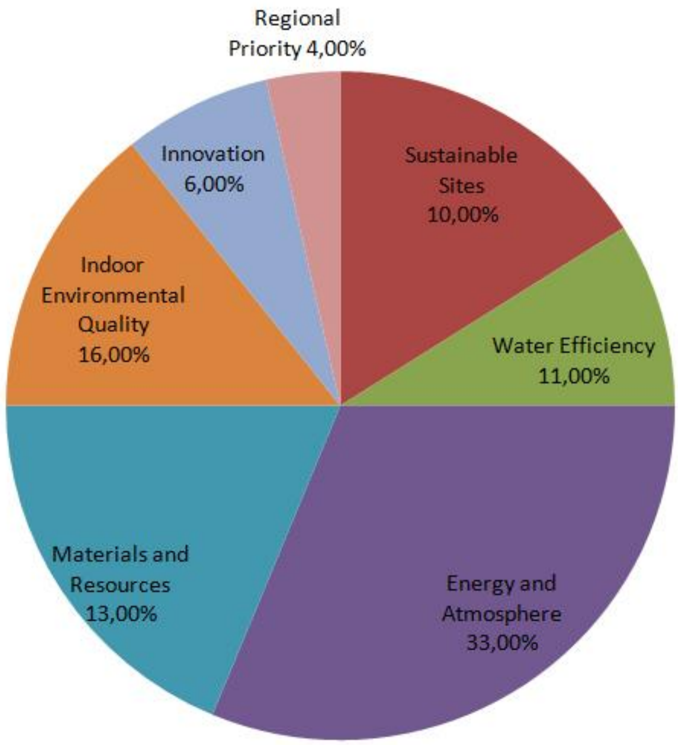


Figure II.3.3_SAM categories' weighting [Source: Chicago Department of Aviation, Sustainable Airport Manual – version 3.2, 2014]

II.3.3.2 *Sustainable Airport Planning, Design and Construction Guidelines*, Los Angeles World Airports

The Department of Airports of the city of Los Angeles - Los Angeles World Airports (LAWA) - owns and operates three airports: Los Angeles International, LA/Ontario Internationa, and Van Nuys Airport.

In 2007 the Board of Airport Co mmissioners (BOAC), responsible for the formulation of LAWA policies, established the adoption of the standards LEED by issuing the executive directive *Sustainable Practices in the City of Los Angeles* for the definition of sustainability programmes to guide every activity, procedure and development strategy. Following this directive, LAWA defines its *Sustainability Vision and Principles* and the *Sustainability Performance Improvement Management System* (SPIMS). SPIMS (Fig. II.3.4) tool set LAWA's objectives and verification parameters concerning the levels of sustainability within a continuous improvement process.
Following application of these standards, the first edition of the *Sustainable Airport Planning, Design and Construction Guidelines* (LSAG) was published in 2008. For the purpose of this research the latest version 5.0 of 2010 has been considered.

Figure II.3.4_SPIMS process [Source: www.lawa.org]

Like the SAM, the LSAG is a tool for monitoring and reporting strategies aimed at planning, design and construction sustainability, and establishes a certification system that mirrors the LEED ones including airport-specific standards and strategies.

Structure

The LSAG is composed of two main parts:

1. *Sustainable planning and design guidelines* and the
2. *Sustainable construction guidelines*

The *Sustainable planning and design guidelines* are further analysed for the purpose of this research. This chapter includes fifteen categories (Table II.3.7) which are specifically related to different stages of planning and include issues such as noise disturbance and climate change adaptation, which were never considered before.

Table II.3.7_LSAG categories and criteria

CATEGORY	CRITERIA
General Planning	Minimize Impervious Areas PD2-GP-2
	Avoid Development of Inappropriate Sites
	Contaminated Site Redevelopment
	Community Education
	Site Protection & Restoration
	Integrated Vegetation & Wildlife Management
	Integrate Sustainability into the Airport Master Plan
Airside Planning	Exterior Noise & Acoustical Control (Aircraft)
	Design Runways, Taxiways & Terminals to Reduce Taxiing Distances & Times
	Design Airside Layout to Reduce Aircraft Delay
	Provide Infrastructure for Alternatively-Fueled GSE in Airside Design
	Provide Infrastructure Planning for Hydrant Fueling for Aircraft
Landside Planning	Exterior Noise & Acoustical Control (Non-Aircraft)
	Minimize Roadway Congestion

	Public Transportation Access
	Bicycle Storage
	Sustainable Parking Facilities
	Support Alternative Fuel Vehicles
	Planning for Future Land Use
Climate Change Adaptation Planning	Increased Temperature
	Severe Weather
	Sea Level Rise and Storm Surge
	Ecosystem Changes
Stormwater Management and Erosion Control	Prevent Downstream Erosion
	Provide Stormwater Treatment
Landscape Design	Reduce or Eliminate Potable Water Use for Landscaping
	Reduce Impact of Fertilizer Use
	Provide Infrastructure for Composting & Vermiculture
Water Efficiency and Conservation	Water Management Plan
	Water Use Efficiency
	Water Reuse & Reclamation
Heat Island Reduction	Heat Island Reduction - Roof
	Heat Island Reduction - Non-Roof
Interior & Exterior Lighting Quality	Exterior Light Pollution Reduction
	Interior Lighting Quality
Noise Pollution Reduction	Interior Noise & Acoustical Control
Energy Efficiency and Conservation	Energy Management Plan
	Energy Systems Commissioning
	Energy Optimization
	Provide Infrastructure for Pre-Conditioned Air
	On-Site Alternative & Renewable Energy
Emission Impact Evaluation and Mitigation	Refrigerant Management/Ozone Protection – Planning & Design
	Greenhouse Gas Emissions – Planning & Design
	Criteria & Air Toxics – Planning & Design
Materials and Resources	Waste Reduction & Management Plan
	Material Durability
	Building Reuse
	Material Reuse
	Recycled Content
	Design Roads for Increased Life Cycle
	Regional Materials PD14-MR-8
	Rapidly Renewable Materials
	Certified Wood
	Wood Preservatives PD14-MR-11
	Low-Emitting Materials
	Furniture & Fixtures PD14-MR-13
	Design for Deconstruction, Reuse & Recycling
	Flexible Systems, Spaces & Infrastructure
Indoor Environmental Quality	Minimum Indoor Air Quality (IAQ) Performance
	Air Quality Monitoring
	Increased Effective Ventilation
	Indoor Chemical & Pollutant Source Control

	Lighting Control
	Thermal Comfort Design
	Daylight & Views
Additional Planning & Design Elements	LEED® Accredited Professional - Planning & Design
	Innovation in Planning & Design

[Source: Los Angeles World Airports, Sustainable Airport Planning, Design and Construction Guidelines – version 5.0, 2010; www.lawa.org]

<u>Point allocation</u>

The level of achievement of the sustainable planning and design performance standards are measured using the *LAWA-Sustainable Rating System*, that defines three different tiers thresholds for projects greater and less than 1.000 square feet (Figg. II.3.8 and II.3.9).

Sustainable Level	Planning and Design Points	Construction Points
LAWA Sustainable Project	≥70	≥25
Business Class	≥80	≥30
First Class	≥100	≥35

Figure II.3.8_LAWA-Sustainable Rating System for projects grater than 1.000 ft² [Source: Los Angeles World Airports, Sustainable Airport Planning, Design and Construction Guidelines – version 5.0, 2010; www.lawa.org]

Sustainable Level	Planning and Design Points	Construction Points
LAWA Sustainable Project	≥40	≥15
Business Class	≥45	≥18
First Class	≥55	≥20

Figure II.3.9_LAWA-Sustainable Rating System for projects less than 1.000 ft² [Source: Los Angeles World Airports, Sustainable Airport Planning, Design and Construction Guidelines – version 5.0, 2010; www.lawa.org]

Differently from LEED and SAM, there are no required prerequisite in the LSAG. Each criteria is associated to a certain number of points. The subdivision in a high number of categories (Fig. II.3.5) makes difficult the comparison with the other rating systems.

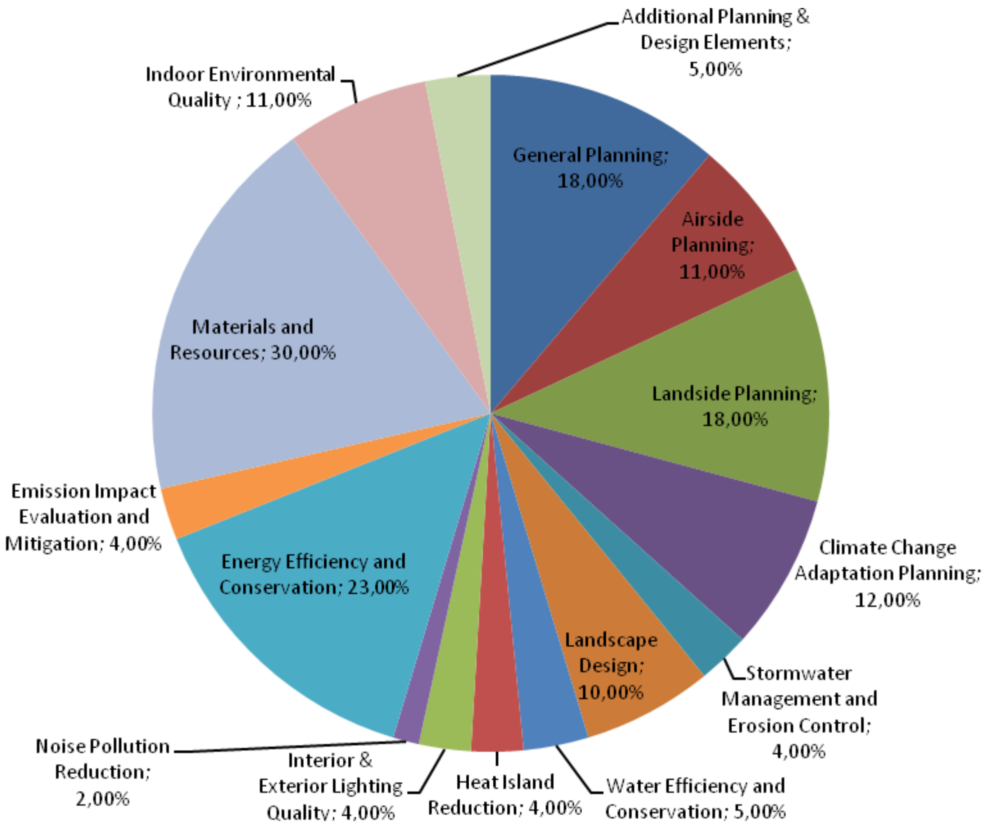


Figure II.3.5_LSAG categories' weighting [Source: Los Angeles World Airports, Sustainable Airport Planning, Design and Construction Guidelines – version 5.0, 2010; www.lawa.org]

II.3.3.3 *Prototype Airport Sustainability Rating System*, Airport Cooperative Research Program

The Airport Cooperative Research Program (ACRP) is a research programme, founded in 2003, managed by the Transportation Research Board (TRB) and sponsored by the Federal Aviation Administration (FAA). ACRP carries out research and develops practical solutions to support airport operators and stakeholders dealing with issues related to: administration, environment, policy and planning, safety, security, human resources, design, construction, maintenance, and operations (www.trb.org). Every year ACRP issues reports and sysntesys on around 20 funded research programmes. At the end on 2014 the Report 119 *Prototype Airport Sustainability Rating System – Characteristics, Viability, and Implementation options* was published. The *Prototype "*identifies the features of a sustainability rating system specifically developed for airports, identifies options for implementing the rating system and a certification program, and evaluates the viability of their implementation and adoption. The report provides a framework upon which a comprehensive airport-centric rating system can be built should the airport industry decide it would be beneficial for assessing its sustainability performance" (ACRP, 2014).

Structure

The Prototype includes practices and strategies for new construction, existing infrastructure and daily operations defining sustainability performances and setting the appraisal paramenters and procedures.

The Prototype includes eightcategories (Table II.3.10).

Table II.3.10_ACRP's Prototype categories and criteria

CATEGORY	CRITERIA
Energy & Climate	Terminal Building Energy Use
	Overall Airport Energy Use
	Renewable Energy Use
	Terminal Building Greenhouse Gas Emission Reductions
	Overall Airport Greenhouse Gas Emission Reductions
	Other Indirect Greenhouse Gas Emission Reductions
	Climate Change Adaptation
Transportation	Fleet Vehicle Fuel Economy
	Airside Equipment Fuel Use
	Alternative Vehicle Fuels
	Alternative Passenger Transportation
	Alternative Employee Commute
Economic Performance	Socially Responsible Financial Investment
	Airport Financial Viability
	Risk Management
	Regional Economic Contributions
Design & Material	Sustainable Design & Operation
	Material Selection
	Construction Waste Diversion
	Construction Impacts Mitigation
	Sustainable Site Selection
	Local Sourcing
	Recycled & Bio-based Content
	Low-Toxicity Materials
	Environmentally Preferable Purchasing
Engagement & Leadership	Airport-Wide Stakeholder Engagement
	Public Outreach EL
	Community Stewardship
	Integrated Sustainability Management
	Airport User Engagement & Outreach
	Tenant & Vendor Sustainability
Water & Waste	Potable Water Conservation
	Waste Reduction
	Waste Diversion
Natural resources	Landscape & Grounds
	Wildlife & Habitat Protection
	Pervious Surface

	Airside Stormwater Quality
	Wildlife Hazard Management
	Heat Island Reduction
Human Well-Being	Airport Noise Compatibility
	Workplace Air Quality
	Light Pollution
	Chemicals & Hazardous Materials
	Passenger Experience
	Employee Development
	Labor Relations
	Diversity & Equal Opportunity
	Occupational Health & Safety
	Universal Design

[Source: Airport Cooperative Research Program, Prototype Airport Sustainability Rating System – Characteristics, Viability, and Implementation options, 2014; www.trb.org]

Chapter II.4 – Airport environmental sustainability: defining the framework of requirements

II.4.1_Airport sustainable development

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.
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. Therefore, 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 (Thomas *et al*., 2001).

Literature and web review 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 assess 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) 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;
- Climate change emissions and carbon management;
- The protection of habitats and biodiversity. and
- The implications of a changing climate for air transport, and specifically airports.

II.4.2_Airport environmental capacity and constraints to growth

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, 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 in Ashford, 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.

II.4.3_The environmental impacts of airport infrastructures

The following sub-paragraphs will explain how different environmental impacts can act as constraints upon airport operations and growth. Different environmental issues are considered in the same systematic way: introduction (including how the issue can act as a constraint to growth; drivers for action; how to measure, monitor, forecast; and manage (through infrastructure, operations, technology, business models).

II.4.3.1 Noise

Noise remains the most clearly identifiable impact on local communities and the environmental issue most likely to mobilise a local residents against infrastructure or capacity expansion. Most of European airports have their operations constrained by noise related issues that threaten their future growth (www.eurocontrol.com; www.europe.eu).

Even though the worst effects act locally, the noise impact can generate significant opposition from residents of communities living further away, along approach and departure routes (Thomas *et al*., 2010b).

Noise emissions are produced by: aircraft in the air, reverse thrust used by aircraft to slow down after landing, aircraft on the ground (including taxiing, engine testing and running on-board electrical generators), departing aircraft that stray from the preferred noise routes (PNRs), road traffic to and from the airport and construction activity (Maughan *et al*., 2001).

Noise disturbance constrains airport operational and infrastructure development when:

- Existing operations exceed:
  - regulatory limits - as demonstrated at Schiphol (Wubben & Busink 2004; Meerburg *et al*., 2007; CAA, 2013; see also www.schiphol.nl) or by the UK Government which has proposed a *Noise Envelope* within which the airport has to

operate (Civil Aviation Authority (CAA), 2013; Airport Commission (AC), 2013) ;
    - planning constraints - as potentially a risk at Manchester (Hume *et al*., 2003a, 2003b; DEFRA, 2010);
    - community tolerance and local agreements - as experienced at Sydney Airport (AC, 2013; see also www.airserviceaustralia.com and www.sacf.infrastructure.gov.au);
- Further development is prevented due to the anticipated noise disturbance – as in the case of Narita International Airport (Miyakawa *et al*., 2008).

Aircraft noise impacts people in a variety of ways primarily depending upon their lifestyle, activities and location (i.e. geography, weather, etc.), (Ashford et al., 2011). The level of perceived nuisance is a function of the frequency and noisiness of aircraft movements, but it is also influenced by additional factors such as health status, annoyance and stress, socio-economic status, cultural, and lifestyle differences (Hume *et al*., 2003a-b). Moreover all these factors are made worse by the fear of air accidents and airport development or disturbance from other airport-related activities (Thomas, 2010b). The level of disturbance perceived by people also depends on magnitude, frequency and duration of the noise which in turn is related to the type and number of aircraft movements .

Noise capacity limits are set through: noise contours, number of houses affected, aircraft types and movements, opening times/runway closure. These factors are measured and defined by:

- Noise events (number of events, peak noise in decibels, duration, time of event, background noise levels);
- Noise climate;
- Noise impacts;
- Perceived level of disturbance;
- Response to that disturbance.

The noise features that can be captured are:

- Maximum sound pressure level – L_{Amax}: it is the highest sound level that occurred during the over-flight, measured in decibel (dB(A));
- Sound Exposure Level – SEL: it is the sound level, in dB(A), of a one second burst of steady noise that contains the same total sound energy as the whole event.

Longer period noise exposure indicators (such as equivalent continuous sound level, number above contours) can balance noise magnitude, noise frequency, noise duration and the number of noise events over a given period.
The *Environmental Noise Directive* (EC, 2002) requires certain airports to map their noise impacts every five years using L_{DEN} (day-evening-night level), a measure which incorporates penalties or weightings for certain hours of the day designed to reflect people greater sensitivity to noise within these periods. The descriptors and indicators measure different noise features, but need to be supported by the

analysis on how they impact on people in order to describe the overall effect of noise levels of disturbance.

Methods for gauging community response include: analysis of noise complaints, social surveys, public consultation and analysis of media coverage. They represent the opportunity for airport managers to communicate with their stakeholders and with the community – as the example of Perth Airport (*Aircraft Noise Information*, www.aircraftnoise.com.au) - in order to demonstrate their commitment to minimise noise negative environmental and social impacts and therefore build tolerance within neighboring communities (Thomas *et al*., 2003).
Following the European Commission's *Operating Restrictions Directive* (2002), the International Civil Aviation Organization (ICAO) has developed the concept of a *Balanced Approach to Noise Management* (2004). ICAO assembly *Balanced Approach* has been recognized as the principle to aircraft noise management. It consists of identifying the noise problem at an airport and then reducing it, aiming to address the noise problem in the most cost-effective manner (AC, 2013).

Noise abatement strategies:

1) AIRCRAFT TECHNOLOGY
Both airframe and engine designs are important in determining total aircraft noise. Aircraft and engine manufacturers have been aggressively researching low-noise technology improvements over the past 50 years and during this time there was a dramatic reduction in the noise output of all aircraft. This has been largely achieved in two ways:

1) Improved aircraft design and updated material types (e.g. aircraft weight and airframe noise).
2) Quieter engines.

2) LAND-USE PLANNING AND MANAGEMENT
The ICAO *Balanced Approach* (ICAO, 2004) to noise identifies three categories for land-use planning and management. These are:

- Planning Instruments: comprehensive planning, noise zoning, transfer of development rights and land and property acquisition.
- Mitigation Instruments: building regulations, sound insulation grant schemes, local property searches, physical mitigation measures.
- Financial Instruments: capital improvement, tax incentives, noise related charges that assist in funding for mitigation and community incentives.

Primarily this aims to ensure that new airport developments are located away from noise-sensitive areas and that only compatible land-use development takes place in areas affected by aircraft noise. This works in two ways, firstly to direct incompatible land use (e.g. houses and schools) away from the airport environs, and secondly to encourage compatible land use (e.g. industrial and commercial use) to locate around airport facilities.
Airport infrastructure design and alignment can also minimize noise disturbance by directing aircraft away from built up areas (e.g. through runway positioning and orientation) or by creating a physical barrier between the operating area and surrounding housing - as in Schiphol Airport.

3) OPERATING PROCEDURES
There are several possible methods for minimizing aircraft noise disturbance through revised operating procedures. The use of each technique is dependent upon the layout of the airport and surrounding areas, along with the aircraft itself. It is important to note that not only do these techniques have varying implications on noise mitigation but a number of these will have some effect on other environmental factors (e.g. increasing carbon emissions when aircraft are required to fly further to avoid overflying urban areas).
The operational procedures are classified by ICAO into three categories (ICAO 2004):

- the use of noise preferential runways to direct the flight paths of aircraft away from noise-sensitive areas;
- the use of specific take-off or approach procedures to optimize the distribution of noise on the ground;
- ground handling procedures to minimize ground noise.

4) OPERATING RESTRICTIONS
Operating restrictions should be a measure of last resort in managing aircraft noise. In evaluating whether operating restrictions are appropriate there is a need to balance the potential benefits to local communities against the potential losses of benefits in connectivity and employment. There are various forms of aircraft noise operating restrictions examples include:

- Night flying restrictions;
- Annual movement limits;
- Ground movement/stand activity/engine testing restrictions.

II.4.3.2 Air quality

After noise, local air quality is one of the other main environmental issues that gives rise to airport constraints, either through regulatory restrictions or community concerns about odours and health fears Airport operators monitor and model air quality in order to demonstrate compliance with regulatory standards (Eurocontrol, 2005; Environmentally Compatible Air Transport System (ECATS), 2010). In Sweden and Switzerland at Arlanda, Gothenburg, Zurich, and Geneva airports, local air quality presents a threat to future operational capacity (ACI, 2010).

Constraints to airport operational and infrastructure development rise when gaseous emissions exceed the emissions standards or air quality limits established by the legislative requirements and regulatory controls for protection of health and environment (www.ec.europa.eu) such as:

1. Directive 2008/50/EC on ambient air quality and cleaner air for Europe;
2. Council Directive 96/62/EC on ambient air quality assessment and management *(Air Quality Framework Directive)*;
3. Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air *(First Daughter Directive)*;

4. Directive 2000/69/EC of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air *(Second Daughter Directive)*;
5. Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air *(Third Daughter Directive)*;
6. Directive 2004/107/EC of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air *(Fourth Daughter Directive)*;
7. Commission Decision 2004/224/EC laying down the obligation of Member States to submit within two years so-called *Plans and Programmes* for those air quality zones where certain assessment thresholds set in the Directives are exceeded;

There are different sources of gaseous emissions arising from the airport operations which affect the air quality in the vicinity of airports (ICAO, 2011):

1) Aircraft emissions
    a. *Aircraft main engines* within a specified operating perimeter (from start-up to shutdown; landing, taxiing, take-off).
    b. *Auxiliary Power Unit* (APU), a self-contained power unit on an aircraft providing electrical/pneumatic power to aircraft systems during ground operations.
2) Aircraft handling emissions
    a. *Ground support equipment* (GSE) necessary to handle the aircraft during the turnaround at the stand.
    b. *Airside traffic.* Service vehicle and machinery traffic within the airport perimeter fence that circulate on service roads.
    c. *Aircraft refueling* through evaporation through aircraft fuel tanks and from fuel trucks or pipeline systems during fuelling operations.
    d. *Aircraft de-icing.* Application of de-icing and anti-icing substances to aircraft during winter operations.
3) Infrastructure-related sources
    a. *Power/heat generating plant.* Facilities that produce energy for the airport's infrastructure.
    b. *Emergency power generator.* Diesel generators for emergency operations.
    c. *Aircraft maintenance.* All activities and facilities for the maintenance of aircraft.
    d. *Airport maintenance.* All activities for the maintenance of airport facilities and for terminal buildings operations.
    e. *Fuel.* Storage, distribution and handling of fuel in fuel farms and vehicle fuel stations.
    f. *Construction activities.* All construction activities associated with airport operation and development.
    g. *Fire training.* Activities for fire training with different types of fuel.
    h. *Surface de-icing.* Emissions of de-icing and anti-icing substances applied to aircraft moving areas and service and access roads.
4) Landside vehicle traffic sources

a. *Vehicle traffic.* Motor bikes, cars, vans, trucks, buses and motor coaches associated with the airport on access roads, curbsides, drive-ups, and on- or off-site parking lots.

Airport capacity assessment concerning local air quality is based on air quality modelling systems, which can be used to forecast future levels of pollution from all of the relevant sources (CATE, 2002).
Regulatory modelling of pollution dispersion has two purposes:

1) Planning for future developments, as in the case of the *Project for the Sustainable Development of Heathrow* (DfT, 2006; Bennet & Hoolhorst, 2010).
2) Attribution of the currently observed concentrations.

Current routine monitoring - as at Frankfurt, Heathrow, Dusseldorf, Schipol (ECATS, 2010) - permits:

- Comparison with regulatory limits.
- Identification of trends.
- Some source attribution.

Air quality legislation has the potential to constrain airport growth either by restricting aircraft movements or road traffic (Upham *et al*., 2003; Bennett & Raper, 2010; Thomas, 2013). Measurement methods and modelling systems can be used to analyse and predict the traffic volumes at which local air quality could constrain the growth of the airport and hence when it will be necessary to develop public transport services to replace car access; while routine monitoring provides a means of assessing the on-going validity of original data (Upham *et al*., 2003).
Emissions reduction measures typically fall into four different strategic categories: regulatory, technical, operational and economic. Examples of each type of strategy are provided in Table II.4.1.

Table II.4.1_Overview of technical/infrastructure measures for emissions reduction

SOURCE	MEASURES
Aircraft	• General airport layout • High-speed runway turn-offs • Parallel taxiways
Aircraft handling and support	• Emissions reduction devices (particulate matter (PM) filter traps, etc.) • Fuel fumes capturing systems
Infrastructure and stationary sources	• Low emissions energy plant, incinerator • Energy conservation measures in new construction and building maintenance • Change in stack heights and location
Landside access traffic	• Enhanced public transit and intermodal connections • Road structure layout • Dedicated public traffic lanes

[Source: ICAO (2011) Doc 9889. Airport Air Quality Manual]

II.4.3.3 Carbon and greenhouse gas emissions

Hotter days, heavier rainfall, increased snow and ice, and more intense storms are some of the direct impacts airports may experience from climate change. Very few airports, however, are considering ways to address these effects. Yet 70% of airport delays are the result of extreme weather, and such weather events are on the increase (*Airport Cooperative Research Program* (ACRP), 2011).

The changing in the climate pattern affects air travel, airport operating and environmental capacity and planning decisions in two different but closely related ways:

1) the carbon emissions related to the airport operational activities will increasingly affect climate change and require the use of effective management and mitigation actions.
2) the implications of climate change will imply infrastructure adaptation strategies and new design specifications in order to comply with the change in the environmental conditions.

The current contribution of aviation sector to the global anthropogenic carbon emissions is estimated at about 3% (***In***tergovernmental Panel on Climate Change (IPCC), 2007). Emissions from air transportation are expected to increase significantly: this contribution may rise to 5% and could reach up to 15% by 2050 (IPCC, 1999 & 2007). In the short and medium term emissions from the aviation sector will continue to increase; this implies that the main focus for the future development policies is to adopt methods for assessing, monitoring and minimising the quantity of carbon emissions. As air transport demand is increasing faster than technological and operational improvement (Thomas, 2013) such that its climate change emissions are forecast to grow for the foreseeable future, the identification of all the sources of pollutant emissions is the basis for an integrated system of mitigation strategies.

To be sustainable, air transport system hat to minimize its environmental footprint while satisfying the transportation need and providing adequate returns on investment (Sgouridis *et al.,* 2011).
In the short and medium term emissions from the aviation sector will continue to increase; this implies that the main focus for the future development policies is to adopt methods for assessing and monitoring quantity and quality of air pollutant and minimizing their emissions. As air transport demand is increasing faster than technological and operational improvement (Thomas, 2013) such that its climate change emissions are forecast to grow for the foreseeable future, the identification of all the sources of pollutant emissions is the basis for an integrated system of mitigation strategies.

Airport operators and international bodies involved in the control and regulation of the activity and development of airport infrastructure have an important role in identifying and prioritizing the best practices for assessing and minimizing greenhouse gas (GHG) emissions effects.

Table II.4.2.a_Typical baseline footprint "Airport System"

	$\%CO_{2eq}$
Flights	90
Transport	6
Food	1
Utilities	2
Materials & Waste	1

Table II.4.2.b_Airport System emission excluding flights

	$\%CO_{2eq}$
Transport	70
Food	5
Utilities	15
Materials & Waste	10

Table II.4.2.c_Contribution of ground transport

	$\%CO_{2eq}$
Co. car scheme	<1
Catering vehicles	<1
Buses	<1
Cargo vehicles	~3
Staff commuting	~5
Passenger access journeys	~90

[Source: Sutcliffe, M. (2005) Applying the Eco-footprint concept and methodology to an airport: Case study of Manchester Airport]

Voluntary programmes, national policies and international regulatory regimes (Table II.4.3) provide a set of requirements and define a comprehensive approach which involves strategies for the identification of sources and pollutants and emissions calculation and quantification.

Table II.4.3_Main global agreements and EU legislative measures which promote the reduction of GHG emissions

United Nations Framework Convention on Climate Change	It is an international treaty produced by the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992. The Treaty aims to achieve stabilization of GHG concentrations in the atmosphere at a level low enough to prevent dangerous anthropogenic interference with the climate system.
Kyoto Protocol	It assigns mandatory targets for the reduction of GHG emissions to signatory nations. Countries that ratified the Kyoto Protocol committed to reduce their emissions of CO_2 and five other greenhouse gases (CH_4, N_2O, HFC, PFC, SF_6). The Kyoto Protocol provides to the Parties means to achieve emissions targets in a cost-effective way through market-based mechanisms such as: emissions trading, clean development mechanism and joint implementation.

	Under the Kyoto Protocol, countries' emissions have to be monitored submitting annual emission inventories or national reports at regular intervals.
Directive 2003/87/EC	It established the European Emissions Trading Scheme (ETS) providing for companies in certain sectors the limitation of GHG emissions under an established cap. The goal of the Directive was to promote reductions emissions of greenhouse gases in a cost-effective and economically efficient manner.
Directive 2008/101/EC	It reviews the Directive 2003/87/EC including aviation activities into EU ETS. It established the criteria for monitoring and reporting emissions from aviation activities, as well as criteria for the verification of emissions from the same activities.
Directive 2009/29/EC	It amended the Directive 2003/87/EC, introduced more stringent emission limits and stipulated that EU-wide quantities of emissions.

[Sources: www.unfccc.int; www.ec.europa.eu/clima/policies/ets/documentation; www.eur-lex.europa]

International law recognises that emissions inventories can support the planning and management of the emissions. GHG inventories can represent the benchmark to measure the achievement of the target levels of emissions set by international standards and regulations. They serve as a framework for monitoring the airport site footprint and evaluate the most effective set of actions aimed at reducing this impact. The inventory can also provide information on the activities that cause emissions and background on the methods used to make the calculations (Giuffrè & Granà, 2011).
For example, Manchester Airport published a carbon inventory (Manchester Airport Group (MAG), 2011) that identified the following key contributors to its carbon footprint and therefore focus of its management strategy:

- passengers journeys to and from the airport (responsible for approximately 60 percent of carbon dioxide);
- energy used for terminal lighting and heating (approximately 20 percent);
- the movement of aircraft on the ground (approximately 20 percent).

The need for greater engagement in carbon management and reporting has been further recognized with the launch of the *Airport Carbon Accreditation* (ACA) scheme under the initiative of Airport Council International (ACI) Europe. The European initiative has seen a rapid increase in engagement in the five years since its introduction, with 86 airports currently accredited (www.aci.org/aca).

The World Resource Institute (WRI, 2004) categorizes emissions into three scopes (Table II.4.4) which identify the ownership and control of emissions sources and thus responsibility for managing the emissions:

- <u>Scope 1</u> are GHG emissions from sources that are owned or controlled by the airport operator.

- Scope 2 are GHG emissions from the off-site generation of electricity (and heating or cooling) purchased by the airport operator.
- Scope 3 are the GHG emissions from airport-related activities from sources not owned or controlled by the airport operator
    - Scope 3A are the Scope 3 emissions which an airport operator can influence, even though it does not control the sources.
    - Scope 3B are the Scope 3 emissions which an airport operator cannot influence to any reasonable extent.

Table II.4.4_Airport emissions sources

SOURCE	DESCRIPTION
Scope 1. Airport Owned or Controlled Sources	
Power plant	Airport-owned heat, cooling and electricity production
Fleet vehicles	Airport-owned (or leased) vehicles for passenger transport, maintenance vehicles and machinery operating both airside and landside.
Airport maintenance	Activities for the maintenance of the airport infrastructure: cleaning, repairs, green spaces, farming, and other vehicles
Ground Support Equipment (GSE)	Airport-owned equipment for the handling and servicing of aircraft on the ground.
Emergency power	Diesel generators for emergency power
Fire practice	Fire practice; Fire training equipment and materials
Waste disposed on-site	Airport-owned waste incineration or treatment from airport sources
Scope 2. Off-site Electricity Generation	
Electricity (and heating or cooling) generation	Emissions made off-site from the generation of electricity (and heating or cooling) purchased by the airport operator.
Scope 3: Other Airport-Related Activities and Sources	
ope 3 Sources an Airport Operator Can Influence	
Aircraft main engines	Aircraft main engines during taxiing and queuing
APU	Aircraft Auxiliary Power Units (APU)
Landside Road traffic/Ground Access Vehicles (GAV)	All landside vehicles not owned by airport operator, operating on airport property
Airside vehicle traffic	All vehicles operated by third parties (tenants, airlines, etc) on airport airside premises
Corporate Travel	Flights taken on airport company business
Ground Support Equipment (GSE)	Tenant or contractor owned GSE for the handling and servicing of aircraft on the ground, if airport could provide alternative fuels or otherwise influence operation.
Construction	All construction activities, usually conducted by contractors.

- **Scope 3B: Scope 3 Sources an Airport Operator Cannot Influence**	
Aircraft main engines	Aircraft main engines in the landing/take-off (LTO) cycle, excluding taxiing
	Aircraft emissions during cruise on flights to or from airport
Ground Support Equipment (GSE)	Tenant or contractor owned GSE for the handling and servicing of aircraft on the ground.
Landside Road traffic/Ground Access Vehicles (GAV)	All landside vehicles related to the airport, operating off-site and not owned by airport operator, including private cars, hotel and car rental shuttles, buses, goods delivery trucks, freight trucks.
Electricity and other external Energy	Emissions from generation of electricity, heating and cooling purchased by tenants including airlines
Aircraft and engine maintenance	Airline or other tenant activities and infrastructure for aircraft maintenance: washing, cleaning, painting, engine run-ups
Rail traffic	Rail traffic and other ground transport related to the airport
Waste disposed of off-site	Off-site waste incineration or treatment from airport sources.

[Scources: Airport Council International (2009b) Guidance Manual: Airport Greenhouse Gas Emissions Management; International Civil Aviation Organization (2011) Doc 9889. Airport Air Quality Manual; World Resource Institute (2004) The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard]

Methodologies for measuring the concentrations of carbon emissions are conducted according to national regulations or standards (ACRP, 2009; *ACI-Europe ACA scheme*, 2009; ICAO, 2011).
In order to reduce emissions stakeholders have set strategies considering all sources of emissions - as identified in the inventory and modeling - and based on four main *pillars* (International Air Transport Association (IATA), 2013):

- Improvement in aircraft technology (including the deployment of sustainable low-carbon fuels);
- Efficient aircraft operations;
- Improved airport infrastructure;
- Positive economic instruments.

<u>Carbon emission reduction strategies</u>:

1) AIRCRAFT TECHNOLOGY

In the last 40 years, airframe design and engine technology improvements have produced aircraft which today are about 70% more fuel efficient per passenger-km (IATA, 2013c). A 20% improvement in fuel efficiency is projected by 2015 and a 40 to 50% improvement by 2050 relative to aircraft produced today (IPCC, 1999).

Also, other fuel options - such as hydrogen - may be viable in the long term, but would require new aircraft designs and new infrastructure for supply.
It is forecasted that the development of new aircraft technologies will take 10-20 years to emerge (IPCC, 1999; Sustainable Aviation, 2012; Thomas, 2013) and will take many years to replace the existing airline fleet and possibly to adapt the current airport infrastructure to the new aircraft models. Given this assumption, airports need to employ operational, infrastructural and business strategies in order to minimize their carbon and greenhouse gas emissions.

2) OPERATIONS

IATA has estimated that CO_2 from commercial airline fuel burn could be reduced by 3.2% in 2020 and by 2.9% by 2030 through airline improved operational practices (Table II.4.5). In addition, 3.2% CO_2 emissions could be avoided if air traffic management systems were optimized (IATA, 2013c).

Table II.4.5_Improvements in Air Traffic Operations

<table>
<tr><td>AIR TRAFFIC MANAGEMENT (ATM)</td><td>- Optimised routing and altitude profiles,
- Reduction of queuing or holding,
- Management of aircraft flows on the ground.</td></tr>
<tr><td colspan="2">The Civil Air Navigation Service Organisation (CANSO) assessed the efficiency of global ATM provision and concluded that there exists an opportunity to improve global ATM efficiency by an average of 3 to 4 percentage points (CANSO, 2008).</td></tr>
<tr><td>AUXILIARY POWER UNITS [1] SUBSTITUTION</td><td>Use of electrical power and conditioned air provided more efficiently from airport infrastructure rather than from the aircraft’s own auxiliary power unit (APU) when the aircraft is on the airport stand.</td></tr>
<tr><td colspan="2">Opportunities to reduce CO_2 emissions from aircraft on the airport stand through the provision of lower-carbon electrical power and/or conditioned air from airport infrastructure rather than from the aircraft’s own APU.
The electrical and air conditioning loads normally supplied by an APU can be efficiently supplied instead by ground based systems, which use grid electricity generated at a higher efficiency and thus have a much lower carbon intensity and will in general offer a much lower cost.</td></tr>
<tr><td>AIRCRAFT OPERATIONS</td><td>- Higher load-factors;
- Optimisation of fuel-loads.</td></tr>
<tr><td colspan="2">- <u>Passenger Load-Factor</u>: an aircraft is at its most fuel-efficient when its load-carrying capacity is fully utilized);
- <u>Optimised Fuel-Loads</u>: it is recognised that on occasions the amount of fuel loaded into an aircraft’s fuel-tanks prior to flight is in excess of that which is actually required to complete the mission.</td></tr>
</table>

[Sources: Sustainable Aviation (2012) *Sustainable aviation CO_2 road-map 2012*; Airport Council International (2009) *Policies and Recommended Practices*

[1] Auxiliary Power Units (APUs) are small gas turbines normally mounted in the rear fuselage of most transport category aircraft. They are used to power electrical systems on board, to run air circulation and conditioning systems and to supply bleed air for starting main engines before or during push back.

Handbook 2009; Airport Operators Association (2010) *Aircraft on the Ground CO_2 Reduction Programme*]

3) INFRASTRUCTURE

Table II.4.6 includes infrastructural strategies for minimizing carbon emissions, divided in four categories:

- Landside layout and ground transport access system;
- Airside layout and Ground Service Equipment (GSE);
- Airport design and resources management.

Table II.4.6_Improvements in Infrastructure

LANDSIDE LAYOUT AND GROUND TRANSPORT ACCESS SYSTEM
- Car emissions can be reduced by discouraging drop-off and pick-up of passengers and providing public transport/mass transit; - Airports can develop themselves as inter-modal transport hubs by including local and region bus and coach facilities, and train stations for local trains, light rail, subway/metro systems, and regional/international trains. Other possibilities include dedicated fast train services between an airport and city centre, and facilities for off-airport and city centre check-in.
AIRSIDE LAYOUT AND GROUND SERVICE EQUIPMENT (GSE)
- Fuel conservation programmes including the use of hybrid cars can reduce mobile equipment emissions.
AIRPORT DESIGN AND RESOURCES MANAGEMENT
Infrastructure design can be the single most significant factor affecting the GHG emissions associated with operating an airport. Engineering and architectural features of new terminal buildings can greatly enhance energy efficiency (LEED[2] and BREEAM[3] building certification programmes can provide guidance). For example, the new Midfield Terminal complex under construction at Abu Dhabi Airport is one of the first in the region to achieve the highest level of green building design and operation with the award of LEED platinum status (www.kpf.com). - <u>New buildings should employ best practice energy efficiency and GHG technology</u> ▪ Underground thermal sinks can be used to enhance heating and cooling efficiencies; ▪ Combined Cooling, Heat, and Power (CCHP) systems use waste heat from electricity generation to heat the terminal in winter. In summer, absorption cycle refrigeration systems can use the same heat source to generate chilled water to cool the building;

[2] Leadership in Energy and Environmental Design
[3] Building Research Establishment Environmental Assessment Methodology

- Smart building technologies can be used to reduce lighting and heating or cooling in unoccupied spaces (e.g. unoccupied escalators can be slowed or paused until people need to use them);
- For large interior spaces in hot climates, thermal stratification can be used to cool occupied areas at floor level while allowing unoccupied space near the ceiling to remain hot;
- In cold climates, new steam plume-suppressing technologies can be used to allow heating plants to be located close to terminal and control tower structures without affecting visibility. This can substantially reduce piping losses and inefficiencies.
- Generation, use or purchase of electricity, heating and cooling from renewable sources including wind, solar, hydroelectric, geothermal, biomass, etc.;

- <u>Existing building should be reviewed for energy efficiency and retrofits conducted where appropriate:</u>
  - A building retrofit project will usually start with an energy efficiency audit. Retrofitting and modifications can cover a wide range of building features including the following examples; Many provide significant operational cost savings, and projects can “pay off” within reasonable time frames.
- <u>New and existing buildings should have best practical thermal insulation and glazing</u>**:**
  - Installation of shading or light-filtering films on windows to reduce solar load;
  - Modifying and modernizing Heating, Ventilation and Air-Conditioning (HVAC) systems, such as installing variable speed electric motors to reduce air flows when occupancy is low or temperatures are mild;
  - Installation of more efficient and long-life light bulbs for both interior and exterior lighting.
- The design of the whole airport infrastructure should consider:
  - Improvements in aircraft taxiways, terminal and runway configuration to reducing taxiing distance and ground and terminal area congestion;
  - Solid waste management that includes recycling and composting, and reduces volumes of waste going to landfills. Reusing excavation and demolition material on-site also reduces transportation emissions.

[Sources: Airport Council International (2009a) Policies and Recommended Practices Handbook 2009; Airport Council International (2009b) Guidance Manual: Airport Greenhouse Gas Emissions Management]

4) MARKET-BASED MEASURES AND CARBON TRADING

Market-based measures - such as environmental levies and emissions trading - are economic incentives to change to activities or equipment with lower emissions, including local emission charges and global or regional emission trading schemes (ACI, 2009a). They have the potential to encourage technological innovation and to improve efficiency, and may reduce demand for air travel (IPCC, 1999). However, this assumption undermine socio-economic benefits of air travelling and its key role for trade and tourism and, by taking away funds from airlines, taxes and charges do not actually incentivize investment in new technology but, on the contrary, weaken the ability of the sector to dedicate resources to newer, cleaner equipment (IATA, 2013c).

Carbon trading is by far the most effective economic instrument to reduce net emissions in the aviation sector (Sustainable Aviation (SA), 2012). Carbon offsetting is a mechanism to provide funding for projects that reduce carbon emissions at another location, in order to compensate for greenhouse gas emissions that cannot be avoided. Offsetting does not in itself support the move towards low carbon air travel (Thomas, 2013) and should not replace emissions reduction efforts.

II.4.3.4 Climate change adaptation

Airport infrastructure operation and development affect the environment but are also affected by the changing climate. Recent extreme natural events – the spread of Icelandic volcanic ash over European airspace in 2010 and the Hurricane Sandy in 2012, to mention the most recent – have shown the need to make airport infrastructure more resilient to the new climate conditions. This also is a *green building* requirement class which asks for more secure and resistant buildings and civil works (Larsen *et al.*, 2011). Extreme weather events, rising temperatures and sea-level, changes in precipitation, put airport infrastructure and operations at risk (ACRP, 2012). Although aviation deals with disruptive weather on a regular basis, such events are likely to become more extreme and more frequent (www.eurocontrol.int). The main objective of the aviation industry is to guarantee infrastructure resiliency, safety, efficient operations and service quality in a changing climate condition.

Airports need to adopt long-term strategic approach to address the need of adaptation to the climate change and mitigation of its impacts on the environment. This will require new designs and materials for future airport infrastructure and retrofitting of existing airport infrastructure. This scenario led to increasing demand of building resilience.

Resilience is the measure of a system to buffer negative climate effects while maintaining its structure and function (IPCC, 2007). A resilient system is the converse of a vulnerable system. It is not sensitive to climate variability and change and has the capacity to adapt (Blanco *et al.*, 2009). In the context of future climate change, a resilient system would be able to operate at its normal capacity given more extreme climate effects such as higher or lower temperatures, greater wind speeds, and increased or decreased precipitation levels. Due to the interconnections between airports and the surrounding region, a resilient infrastructure could contribute to building overall network resilience encouraging the spread and development of climate change adaptation measure on the whole territory (Burbidge, 2014).

Key factors when determining the appropriate responses to this challenge are based on a climate change risk-assessment methodology and are aimed to:

- identify the met consequences of climate change;
- indicate time scales over which they are likely to occur;
- assess implications for airport infrastructure, operations, and capacity;
- evaluate the magnitude of the impact;
- specify which are the most cost-effective and sustainable design, operational and business adaptation practices;
- determine the time frames limits for the proposed practices to be effective (short, medium, long term planning);
- develop an adaptation action plan.

An example is represented by Birmingham International Airport which produced a climate change adaptation action plan based on a tool called BUCCANEER (Birmingham Urban Climate Change and Neighbourhood Estimates of Environmental Risk), included as a future method of assessing the airport's risk to climate change (www.birminghamairport.co.uk). Climate modeling was used to demonstrate how climate change could affect the airport and the services it provides and provide information on climate variables. The use of probabilistic projections of climate change for different scenarios provide a set of information (e.g. rainfall, temperature, cloud, sea level rise, storm surge, etc.) that directs project design decision process. The definition of the high priority climate related risks represent the basis for the definition of the adaptation action plan. Many airports in the UK are adopting this approach to define their own climate adaptation strategies (e.g. Heathrow, Stansted, Edinburgh, Glasgow).

The development and delivery of the adaptation strategy is a continuous and ongoing activity that responds and adapts to new and improved information on the science and understanding of critical thresholds.
In table x the main climate threats to airport are identified based on the literature (NATS, 2011; Larsen *et al.*, 2011; ACRP, 2012; DEFRA, 2012; Eurocontrol, 2013b). For each impacts, constraints to the infrastructure development and operation are described and technological and design solutions are suggested in order to comply with the resilience requirements, as shown in Table II.4.7. European and international case studies are presented in order to illustrate some of the good practices already adopted for minimising the risks of climate change.

Table II.4.7_Potential climate change effects and illustrative responses for airports

IMPLICATIONS OF CLIMATE CHANGE	CONSTRAINT ON INFRASTRUCTURE AND OPERATIONS	DESIGN SOLUTIONS
Temperature Change		
• Temperature rise • More hot days • Increasing in extreme temperature days • Fewer cold days • Temperature swing above and below freezing	Extreme heat can produce **pavement buckling** (e.g. concrete expansion while remaining rigid) and **loss of pavement integrity** (e.g. tarmac melt) Increase in temperature will **increase demand in energy** for cool air conditioning systems **Permafrost thaw** causing subsidence of runways and other airport infrastructure and damages on airfields, airstrips, access roads Changes to **freeze/thaw cycle** of road subsurface and building envelope materials Increasing **urban heat island effect**	➢ Higher temperatures will mean a decrease in aircraft lift, requiring longer runways at some airports ➢ Utilize heat-resistant paving materials ➢ At 40–100 years in the future, consider possible significant impact on pavement and structural design (e.g. select materials and equipment with durability in high temperatures; design concrete structures for subsidence) ➢ New design specifications will be required for future airport terminals and retrofitting of existing terminals to improve thermal efficiency and reduce energy requirements for passenger comfort ➢ Include energy efficiency and renewable energy measures and design for redundancy ➢ Existing infrastructure will need to be refurbished with new construction materials ➢ Design building and envelope considering: - Interior and exterior shading devices - High performance glazing - Proper insulation systems and materials - High albedo roofing and paving - Green roofs - Ice dam resistant construction - Cross ventilation

Precipitation Change		
• Increase in heavy precipitation events • Increased extreme rainfall events • Higher intensity /longer duration of precipitation	Airfield, roads, bridges, stormwater **decreased capacity of drainage systems** Increased **runoff** from paved areas	➢ Increased overload and backup of stormwater drainage systems and combined sewer system have to be considered ➢ Increase capacity of stormwater conveyance and storage ➢ Install or improve stormwater treatment systems systems ➢ Include rainwater harvesting and reuse systems ➢ Increase envelope capacity collecting rainwater ➢ Oversized roof drainage ➢ Minimise impervious surfaces
• Seasonal changes in fog	High levels of **humidity**	➢ Consider damages to the envelope materials and components ➢ Evaluate decreasing in the envelope capacity to ensure indoor air quality (temperature, mould, etc.)
• Drought	Changes in the ability to meet demand due **water shortages**	➢ Maximise opportunity for water harvesting ➢ Improve water management practices
Sea-level Rise		
• Sea-level rise • River-level rise	**Rising water levels** in coastal areas and rivers	➢ Airport relocation because of the long-term threat from increasing sea levels - which will lead to an increasing land use ➢ Include protective dikes, containment walls and levees ➢ Elevate facilities and runways ➢ Salt damage to materials and components ➢ Design building and envelope considering: - Materials resistant to brackish and saline waters

Extreme Events		
• Increase hurricane intensity • More intense aspects of storms: precipitations, winds, wind-induced storm surge, greater wave height	Increased **pressure** on structures, components and materials Increase in **winter storms**, with increases in winds, waves Potential changes in **storm track location and strength** **Snow, sleet, blizzard, ice**	➢ New structural and materials specifications will be required in order to resist to pressure and erosion ➢ Use pervious pavements for roadways, shoulders, non-traffic pavements, maintenance roads, utility yards and airside and landside parking facilities ➢ Use vegetated green-roof systems to reduce runoff from buildings ➢ Design for curb breaks, drainage ditches, basins and/or bioswales
Wind Load		
• Increases and decreases in wind speed and loading • Change in prevailing wind	**More turbulence**, which has a primary effect on runway utilization through reductions in take-off and landing rates causing backlog, delays etc.	➢ Consider decreased ability in natural ventilation ➢ New structural and materials specifications will be required in order to resist to pressure, wind load and erosion
Ecosystem Change		
• Seasonal changes in fog	**Changes in wildlife and vegetation** - such as possible effects of bird strike risk resulting from changes to migration patterns and changes in vegetation growth Increased **vulnerability to wildfires** near forester areas	➢ Landscaping has to consider future precipitation and temperature patters ➢ Consider increased dependence on irrigation systems to maintain landscaping ➢ Fire-safe landscaping ➢ Design building and envelope considering: - Non-combustible materials and components

[Sources: adaptation of the author from ACRP (2012); NATS (2011); DEFRA (2012); Eurocontrol (2013b); Larsen et al. (2011)]

II.4.3.5 Energy and water use

Airports require a guaranteed, adequate and appropriately priced supply of resources (i.e. energy and water) in order to meet peak demand from their service partners and passengers and therefore maximise their operational capacity. The maintenance of ambient temperature and air quality within terminal buildings to ensure passenger comfort accounts for the single most significant contribution to energy use at the majority of airports. At the same time, airports use large quantities of water to maintain essential services.

The main source of energy consumption are:

- Maintenance of ambient temperature and air quality within terminal buildings (passenger comfort);
- Retail and commercial activities;
- Airfield electricity consumption;
- Airport vehicles and ground service equipment converted to energy-efficient types.

The main source of water consumption are:

- Drinking, catering, retail;
- Air conditioning systems
- Cleaning, flushing toilets;
- System maintenance and engineering;
- Ground maintenance and landscaping.

The demand for resources is constrained by the decline of supply availability and/or the increasing costs. These factors are even more critical if we consider their impact on the surrounding areas and the city (e.g. increasing competition for grid supplies). As regard water consumption, another driver for action is the declining of water resources due to: natural resources being over exploited; landscape change (loss through runoff); climate change (increased demand, less rainfall). This complex scenario places significant economic and political pressure on airport managers to accurately assess their airport's performance and minimise the airport's environmental footprint.

Drivers for action are therefore: to meet customer demand, to maintain levels of service, to maintain infrastructure, whilst reducing costs and quantities used - for sustainability reasons and to adapt to a changing climate.

The most sustainable approach to resource management is for airports to seek to become self-sufficient in energy and water supply by minimising consumption, using efficiently, harvesting, reusing water and employing low carbon emissions source of energy.

1) KEY STRATEGIES – ENERGY

Infrastructure design, technologies and management systems employed will ensure minimum use of energy across the site. These same actions will minimise carbon emissions. Energy supplies will be secured through the incorporation of renewable energy generation into airport infrastructure. Some airports have invested in their own power-generation systems. For example, Athens International Airport in Greece has constructed a photovoltaic installation comprising almost 29,000 photovoltaic panels with a power output of 8.05 MW, accounting for some 20 percent of its energy demand (www.aia.gr).

- Use of non-renewable and polluting energy sources should be reduced while sustainable energy sources should increasingly supply airport energy needs.
- Designing and constructing a new building provides many opportunities to implement energy efficiency technologies. “Green designs”, “smart” building management systems and the like are much more easily incorporated at the planning and design stages, but many can be installed as a retrofit to an existing building. Building energy efficiency features can include the following:
  - Building orientation to maximize benefit of local weather and solar conditions.
  - Insulation of roof spaces and walls, and use of thermal double glazing.
  - Natural ventilation to reduce or avoid the need of air conditioning.
  - Planting (e.g. deciduous trees), tinted glazing and operable window shades to minimize summer solar heat load and maximize winter heat gain.
  - Renewable energy sources (photo-voltaic cells, wind or solar energy, etc.).
  - Natural lighting and other building features and materials that require little maintenance or resources for operations.
  - Low energy lighting (e.g. light emitting diodes (LED), compact fluorescent bulbs) both internal (terminals, offices etc.) and external (runway, tarmac, roads etc).
  - “Smart” building and control techniques – utilizing automatic control systems that regulate energy use according to occupation and other factors.
  - Simplification of plumbing infrastructure requiring less pumping.
  - Optimization of heating, hot water, and electrical infrastructures to minimize loss and degradation over the system.
- Heating, Ventilation and Air Conditioning (HVAC) is one of the major energy consumers at most airports. Efficiency improvement projects can have short payback periods and provide both climate change and local air quality benefits. Many traditional and innovative technologies are available, some for new installations and some as retrofits:
  - Natural ventilation and offices with operable windows can be used during temperate condition.

- Efficient lighting systems including low energy and long-life bulbs and reduced lighting in unoccupied spaces.
- Smart building technologies can be used to reduce lighting and heating or cooling in unoccupied spaces.
- Underground thermal sinks can be used to enhance heating and cooling efficiencies.
- Combined cooling, heat and power (CCHP) systems use waste heat from electricity generation to heat the terminal in winter. In summer, absorption cycle refrigeration systems can use the same heat source to generate chilled water to cool the building.
- Modifying and modernizing Heating, Ventilation and Air-Conditioning (HVAC) systems, such as installing variable speed electric motors to reduce airflows with occupancy is low or temperatures are mild.

Energy efficiency is not a new concept among airport operators and designers. Kaszewski and Sheate (2004) cite several airports that have adopted 'green design'; for example, Stansted (UK), Barajas-Madrid (Spain), and Chep Lap Kok (Hong Kong) airports have all maximized the use of natural lighting in their terminal buildings. These buildings also incorporate very high standards of insulation and high heat-recovery air-conditioning systems (ACRP, 2010a).

2) KEY STRATEGIES – WATER

Water use will be minimised the introduction of a dual water system across the site, through water reuse, recycling and purification systems – as at Hong Kong International Airport (www.hkairport2030.com) and Beijing Capital International Airport (www.en.bcia.com.cn) - as well as technologies and operational systems to minimise wastes. Other sources of water comes from desalination plants and collecting and storing rainfall. At Singapore Changi Airport, rainwater harvesting provides almost a third of the water needs (www.changiairportgroup.com).

- The main uses of water include bathrooms and toilets, catering, laundries, cleaning, landscapes and gardens, aircraft and vehicle washing and aircraft potable water supply. Other uses include runway de-icers, construction, and maintenance. Sources of water include municipal supply, underground aquifers, surface water (including artificial dams) and rain water (from building roofs). Some airports have their own wastewater processing plants. Good water management practices include the following:
    - Installation of water saving devices such as waterless urinals, infrared toilet flush controls, self-closing sink taps and low flow shower heads.
    - Rain water collection and grey-water recycling for non-potable uses such as toilet flushes and landscape (garden watering).
    - Computer-controlled, "smart" irrigation systems
    - Water-efficient central heating and cooling systems

- Water recycling of vehicle wash and other lightly contaminated effluents.
- Prevention of incidental loss through leakage.

II.4.3.6 Waste

Sustainable development acknowledges the fact that the earth's resources are limited and that their extraction, consumption, and disposal have significant environmental impacts (Thomas & Hooper in Ashford, 2011).
Airport operations, aircraft, and passenger handling all have the potential to generate significant quantities of waste, as illustrated by Hartsfield-Jackson Atlanta International Airport, which handled almost 90 million passengers in 2011 and generated over 70 tonnes of solid waste every day (Hartsfield-Jackson Atlanta 2011 Sustainability Report; www.atlanta-airport.com).

The concern about the production of wastes arises from the close relationship between the economic growth and the increasing consumption of resources, the fact that the Earth's resources are limited and the significant economic and environmental costs associated with the handling and disposal of wastes . The amount of resources needed to deliver adequate customer services, to provide for the normal operation of the airport and the maintenance of its infrastructure, involves issues related to environmental contamination and waste management, as they can both impact on the entire infrastructure design and layout (e.g. need of adequate space for the collection, storage, segregation and disposal of recyclable materials, or the provision of a waste to energy plant), on operational activities (i.e. associated responsibilities, costs and potential profit) and above all on the risk of surface and groundwater contamination.

The main areas and sources of waste generation on the airport include the following:

- Terminal (cleaning, catering and retail);
- Aircraft (engineering, cleaning and catering);
- Office, hotels, etc.
- Maintenance activities;
- Landscape management;
- Cargo handling;
- Construction activities.

The main areas of waste generation on the airport include the following, as exemplified for London Stansted Airport:

- Terminal (cleaning, catering and retail);
- Aircraft (cleaning and catering);
- Office, hotels, etc.
- Maintenance activities;
- Landscape management;
- Cargo handling;
- Construction activities.

Drivers for waste management include international and national regulatory requirements, the increasing cost of waste treatment and disposal, the practicalities of handling large quantities of waste, and an acknowledgment of corporate responsibility. Although waste management regulations differ between countries and even between states, they do have common features relating to:

- The handling of "special" wastes that are harmful to humans or the environment or have been transported across national borders, including chemicals, clinical and radioactive wastes, and foodstuffs;
- Prioritizing waste minimization in order to reduce the generation of waste in the first place, before other management options are considered;
- The need to promote the reuse and recycling of materials and dissuade the dumping of waste in landfills;
- The opportunities of waste to energy generation through incineration.

In the development of their strategy, airports have to consider the waste they are expected to produce in the future. A forecast of waste is based on the prediction of waste produced by the airport facilities and generated by passenger throughput. The waste production forecast – based on number of passengers and type of flights (e.g. short haul, low cost flights tend to generate less waste than international, long haul flights) forecasts – can ensure that the sustainability strategies and collection services remain fit for purpose and meet demand (e.g. *Making a material difference.* London Stansted Airport Waste Management Strategy 2010-2015, www.stanstedairport.com).

Sustainable waste management seeks to minimise the amount of waste generated in the first instance but then acknowledges that waste materials, if properly segregated, are valuable resources that can deliver significant financial returns as well as environmental benefits. A key to reducing waste at the source is minimisation at the point of purchase through the supply chain (e.g. minimise product packaging and maximise opportunities for the return of packaging). This can however, have infrastructure implications, if, for example the airport operator chooses to bulk buy products to reduce packaging and handling costs.

The separation of wastes on site allows the airport operator to reuse or sell materials to external contractors, or use them for composting or energy generation in contrast to having to pay external companies to collect and then process the untreated waste. For example, all waste from facilities under Swedavia (operator of ten Swedish airports) is sorted and divided into three categories: waste for energy recycling (70%); waste for materials recycling (29%); and waste for landfill (1%), (Swedavia annual report and sustainability report 2013; www.swedavia.com).

Airport waste management requires engagement with a large number of companies (i.e. the airport operator, airlines, handling agents, maintenance companies, retail outlets, and other service partners) and needs to address the specific challenges offered by airside safety and security issues arising from the transfer of materials across the airside-landside boundary. For these reasons, a comprehensive site-wide waste management – as at Frankfurt Airport (www.fraport.com) and London Heathrow Airport (www.heathrowairport.com) – is the most economically and operationally effective approach, with the airport operator as the only corporate entity leading on the development of strategy, management, monitoring and reporting systems.

The principles of what is known as the "waste management hierarchy" (*Waste Framework Directive* 2008/98/EC) seek to:

- reduce the production of wastes in the first instance;
- maximise opportunities for the reuse and recycling of materials;
- minimise the amount of waste that is subsequently disposed of in landfills.

II.4.3.7 Water pollution

Airport's indoor and outdoor activities (Table II.4.8) have potentially significant implications for surface and groundwater pollution (Ashford *et al*., 2011). Pollutants and activities associated with their emission are diverse and require a variety of treatment systems and the coordination of all service partners engaged in the environmental management system. The airport operator has a central role in coordinating the environmental management system with which all service partners have to engage.

Table II.4.8_Principal indoor and outdoor activities which impact on water contamination

ACTIVITY	POTENTIAL SOURCES OF WATER POLLUTION
Aircraft ground handling	Fuels, oils, sewage
Aircraft, vehicle, stand washing	Detergents, oils, solids, carbon residues, heavy metals
Airfield maintenance	Runway rubber residues Oils, paint-stripping chemicals, kerosene, solvents Agricultural activities, including fertilizers, pesticides, herbicides
Winter operations	Runway and aircraft de-icing and anti-icing chemicals, urea
Fire service training	Oil and firefighting foams
Solid and liquid waste disposal	All wastes from infrastructure and operational activities
Heavy rainfall	Wastes associated with the fueling, operation, and cleaning of aircraft may also be carried to nearby lakes and streams through the storm drainage system

The primary drivers for action to prevent water pollution include regulatory requirements (aquifers protection, public health, water resource shortage), the need to minimise operating costs, and - in the event of spills - associated environmental cleanup charges (Thomas & Hooper in Ashford, 2011).

As environmental regulations tighten, the ability to monitor for aviation contamination has become essential. In order to monitor the quality of water and its levels of contamination, sensors are installed at various locations around the airport. In order to implement effective measures of prevention it is essential to determine which areas of the airport are likely to be subject to different risks in terms of surface and groundwater pollution. The different catchment areas that feed underground drainage systems around the airport estate are affected by the geographic distribution of aprons, taxiways, runways, terminal buildings, and maintenance and other infrastructure across the site (Thomas, 2013) and are therefore linked to the overall infrastructure design.

The effective control of water contamination depends on:

- The design of infrastructure
- The development of specific operational practices;
- The selection of appropriate materials;
- The implementation of strict handling and spill-response procedures.

1) INFRASTRUCTURE PRACTICES
   - Drainage infrastructure:
     - Catchment areas feed underground drainage system
     - Settlement tanks
     - “First flush” collection
     - Automatic monitoring and flow diversion
   - Diversion to mains drainage
     - Many airports divert dirty water into the mains sewerage system for treatment offsite
     - Significant costs for reserving capacity within the mains system for airport use
     - Many chemical pollutants from airport activities not appropriate for such an approach so pre-treatment on site may be necessary
     - More cost effective/sustainable “on site” treatment methods may be appropriate – implications for infrastructure design

2) OPERATIONAL PRACTICES
   - Operational practices:
     - Strict handling procedures
     - Spill response procedures
     - Strict storage and handling procedures
     - Specific, clear and well documented handling procedures
     - Training, awareness building, motivation

Table II.4.9_Factors that affect water quality and Specific solutions – Infrastructure practices

INFRASTRUCTURE PRACTICES
- The location of a development project within the airport watershed can impact the degree to which surface water quality management becomes a significant issue. When assessing sites in early project planning phases, the presence of groundwater resources should be a significant factor in the decision-making process. - Modify design of drainage system or utilities to prevent potential drainage or leakage to protected groundwater. - The vast impervious areas associated with airports and airport developments often result in greater peak storm water discharge rates and greater volumes of storm water runoff into receiving streams or water bodies. Airports should properly evaluate reduction and flood control measures likeretention of peak storm events.

[Sources: Airport Council International (2009) Policies and Recommended Practices Handbook 2009; Airport Cooperative Research Program (2011) A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning]

Table II.4.10_Factors that affect water quality and Specific solutions – Operational practices

OPERATIONAL PRACTICES
- Pollution control systems for storm water, especially for deicing-driven controls and sediment controls, can require significant amounts of space for storm water storage. - Use soil probing, sampling, or drilling techniques to characterize groundwater in advance of construction and allow for long-term monitoring of groundwater. - Use of best management practices, specialized protocols, and trained personnel to apply, store, handle, and dispose of chemicals and pesticides may reduce project impacts and control needs.

[Sources: Airport Council International (2009) Policies and Recommended Practices Handbook 2009; Airport Cooperative Research Program (2011) A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning]

3) APPROPRIATE MATERIALS
   - Material used for airport related activities:
     - Low impact products
     - Use according to instructions
     - Just in time use
     - Alternatives to use chemicals

Table II.4.11_Factors that affect water quality and Specific solutions – Appropriate materials

APPROPRIATE MATERIALS
- Airports should consider means and methods to reduce the use of chemicals outdoors to the extent practicable. - Changes to operating practices can be introduced to reduce chemical use. - The purchase and use of less environmentally damaging (eco-friendly) materials and products.

[Sources: Airport Council International (2009) Policies and Recommended Practices Handbook 2009; Airport Cooperative Research Program (2011) A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning]

4) SPILL-RESPONSE PROCEDURES
   - Spill response to accidents:
     - Fuel and chemical spillage
     - Emergency plans and maintenance programmes
     - Major role for airport fire service

Table II.4.12_Factors that affect water quality and Specific solutions – Spill-response procedures

SPILL-RESPONSE PROCEDURES
<u>Fuel spills</u> - The possibility of major spillage events needs to be taken into account in the design of the airport and its drainage systems, interceptor capacity and storm water management. - Remedial action options usually cover containment and soil and ground remediation. <u>Fire fighting training facilities</u> - Fire fighting training facilities should be designed to minimize chemical and fuel release. The use of impermeable containment basins, as well as environmentally sound fuel storage and distribution system should be considered at all fire training facilities.

[Sources: Airport Council International (2009) Policies and Recommended Practices Handbook 2009; Airport Cooperative Research Program (2011) A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning]

5) REUSE AND SUSTAINABLE SOLUTIONS
   - Water recycling
     - Water recycling plants can process water for reuse
     - Not all pollutants can be handled
     - Financial implications
   - Sustainable solutions

- Surface water runoff from hard standing through "natural" clean up systems (e.g. microbes "seeded" onto crumpled car tyres; reed beds[4])

Table II.4.13_Factors that affect water quality and Specific solutions – Reuse and Sustainable solutions

REUSE AND SUSTAINABLE SOLUTIONS
The following storm water treatment systems can be considered, as appropriate: - vegetative swales, - oil-water separation devices, - dry-type detention basins, - sediment settling basins/traps, - infiltration basins. Prior to considering any type of onsite treatment system, airports should also consider potential wildlife attractants and consider appropriate procedures to mitigate this potential.

[Sources: Airport Council International (2009) Policies and Recommended Practices Handbook 2009; Airport Cooperative Research Program (2011) A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning]

II.4.3.8 Habitat

Airports have been usually built out from the urban conurbation in open countryside or in "green belt" areas, in order to have land availability for future expansion and reduce impacts on the nearest cities and communities (Upham *et al*., 2003). The increasing awareness about habitats protection and biodiversity and the associated evolution of international and national regulations[5]. The potential threats to the ecological value of local habitats and eco-systems represent a constraint for airport operational capacity and infrastructure expansion in the surrounding territory: they can affect aviation infrastructure growth (e.g. terminal, runway) but also supporting infrastructure (e.g. rail and road access).

Sustainable development would require that airports compensate for their adverse ecological impacts through landscape and habitat management, mitigation, and compensation programs (e.g. Manchester Airport Group, *Environment Plan - Part of the Manchester Airport Master Plan to 2030*, 2007). The challenge of protecting biodiversity while facilitating airport growth is

[4] Reed beds can be designed to remove contaminants such as organic waste, hydrocarbons and heavy metals. The type of reed bed employed is engineered specifically to the type of waste water and individual requirements of the particular industry. Zurich Airport in Switzerland saw one of the first installations of a reed bed for the treatment of glycol in the world. In 2001, British Airport Authority (BAA) began a £22 million, 10-year project at London Heathrow Airport – the *Heathrow Constructed Wetlands* – one aspect of which was a trial to treat runway runoff using rafted and subsurface flow reed beds (*Natural waste water treatment: using reed beds at airport*, www.armgroupltd.co.uk).

[5] E.g., the *Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora* and the *Directive 2009/147/EC on the conservation of wild birds* (see www.ec.europa.eu)

exacerbated, however, by the issue of bird hazards to aircraft (ACI, 2013b). Airports attract a wide range of wildlife which represent a threat to aviation and need to be controlled. Land uses such as landfills, lakes, marshes, wetlands, reservoirs, etc., may attract wildlife which should be discouraged or if unavoidable, should be managed, keeping aviation safety as a priority (ACI, 2009a). There can therefore be a conflict between the development of ecological mitigation measures and aviation safety, an issue that has arisen at a number of airport developments in the UK including Heathrow, Stansted and Manchester.

Within the airport boundary control is best exercised by denying wildlife access through the effective use of fences and other barriers. However, main measures dealing with habitat protection and biodiversity, are related to landscaping. Habitat management, including grass management, should be employed to minimize the attractiveness of airport lands to wildlife. Insofar as possible, wet land and stagnant water on aerodromes should be drained. Buildings can also provide numerous opportunities for roosting and or nesting by birds and are often inhabited by small mammals. Analysis of buildings can identify places that can be used by wildlife. The elimination of these potential shelters will decrease the numbers of animals present. Aerodrome operators may need to obtain advice from specialists working in conjunction with local agronomists on the seed mixes to be used for planting on the airfield. The mix should permit development of slow-growing plants producing a minimum of seeds, to avoid providing food for birds, yet with sufficient regeneration to maintain good soil coverage (ACI, 2013b). Climate change patterns should be also considered when choosing species to be implanted.

II.4.4_GrADE general framework: draft proposal

A comparative table has been used to compile, sort, and filter categories, activities, metrics, and from the five rating systems analised in Chapter 3. The table was used to organise, associate, consolidate, and evaluate these elements to select suitable sustainability requirements, sustainability activities, performance metrics, and actions for the definition of the *Green Airport Design Evaluation* (GrADE) general framework.
In order to organise the content of the table, seven categories have been defined based on the analysis of the airport-related environmental impacts (as illustrated in the previous pararaphs, namely: noise, air quality, carbon and greenhouse gas (GHG) emissions, energy use, water use, waste and materials, water pollution, biodiversity and land use. For the purpose of this research the environmental issues related to climate change adaptation and resilience are not considered due to the complexity of the topic, that needs to be treated in a more specific research. In fact, it has been noted that climate change could not represent a category for itself, but has an impact on each of the categories considered in this research. Further research developments will be aimed at integrate adaptation aspects to climate change into all the parts of the GrADE framework and tools.

In the following pages:
Table II.4.14_GrADE final set of categories and sheet. The boxes highlighted in blue represent a correspondence of the requirement within a specific rating system.

CATEGORIES	REQUIREMENT	INTENT	BREEAM	LEED	CDA	LAWA	ACRP
NOISE	**Design considering noise zoning and compatible land use development**	Reduce the likelihood of noise arising from fixed installations on the new development affecting nearby noise-sensitive buildings **(Reduction of noise pollution)** and promote compatibility between airports and surrounding communities by minimising noise from aircraft operations and construction activities **(Airport noise compatibility)**					
	Design airside layout to reduce noise emissions	Develop acoustical control measures during the planning phases regarding runways, taxiways and aircraft maintenance facilities to reduce exterior noise levels from aircraft noise sources **(Exterior Noise & Acoustical Control)** and mandate that new or modified airside facilities be planned with the purpose of reducing taxi distances and times to the maximum extent practicable to reduce emissions **(Design Runways, Taxiways & Terminals to Reduce Taxiing Distances & Times)**					
	Provide physical mitigation barriers between operating areas and the surroundings	Develop acoustical control measures during the planning and design phases to reduce exterior noise levels from stationary and mobile noise sources **(Exterior Noise & Acoustical Control)**					

	Design to reduce indoor noise from outdoor sources	Ensure the building's acoustic performance including sound insulation meet the appropriate standards for its purpose **(Acoustic performance)** and limit noise levels in noise-sensitive, occupied spaces such as passenger terminals and offices to increase employee productivity and passenger comfort **(Noise Transmission)**					
AIR QUALITY	**Evaluate magnitude of different emissions sources**	Understand potential criteria and air toxics emissions from proposed designs and structures, ensure consistency with regulatory requirements and develop mitigation measures to reduce potential new or cumulative impacts **(Criteria & Air Toxics – Planning & Design)**					
	Design and employ systems to enhance indoor air quality	Recognise and encourage a healthy internal environment through the specification and installation of appropriate ventilation, equipment and finishes **(Indoor air quality)** and establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants **(Minimum Indoor Air Quality (IAQ) Performance)**					
	Employ low emitting systems and materials	Reduce concentrations of chemical contaminants that can damage air quality, human health, productivity, and the environment **(Low-Emitting Materials/ Low-Toxicity Materials)**					

CATEGORIES	REQUIREMENT	INTENT	BREEAM	LEED	CDA	LAWA	ACRP
CARBON AND GHG EMISSION	**Design landside layout to minimise roadway congestions**	Minimize emissions related to roadway congestion and idling automobiles **(Minimize Roadway Congestion)**				■	
	Reduce parking footprint	Encourage the use of alternative means of transport other than the private car to and from the building, thereby helping to reduce transport-related emissions and traffic congestion associated with the building's operation **(Maximum car parking capacity)**	■	■	■	■	
	Develop infrastructure to increase public transport	Recognise and encourage development in proximity of good public transport networks, thereby helping to reduce transport-related pollution and congestion **(Public transport accessibility/Other Indirect Greenhouse Gas Emission Reductions)**	■	■	■	■	■
	Provide bicycle facilities for the employees	Increase bicycle and other human-powered vehicle (HPV) use in order to reduce personal vehicle usage **(Alternative Transportation)**	■	■	■	■	■
	Design infrastructure and buildings to minimise carbon and GHG emissions	Encourage the adoption of design measures, which reduce building energy consumption and associated carbon emissions **(Low carbon design)**	■	■	■	■	■

ENERGY USE	**Employ energy efficient transportation systems and equipment**	Recognise and encourage the specification of energy efficient transportation systems **(Energy efficient transportation systems)** and provide infrastructure in terminal buildings and gates to support the use of preconditioned air by aircraft as part of new construction, renovation and retrofit projects **(Provide Infrastructure for Pre-Conditioned Air)**					
	Design and upgrade buildings to reduce energy consumption	Recognise and encourage buildings designed to minimise operational energy demand, primary energy consumption and CO_2 emissions **(Reduction of energy use)** and achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic harms associated with excessive energy use **(Optimize Energy Performance)**					
	Design and upgrade buildings to reduce energy consumption for lighting	Recognise and encourage the specification of energy efficient light fittings for external areas of the development **(External lighting)** and achieve increasing levels of interior lighting quality to increase energy efficiency and reduce environmental impacts associated with lighting products. **(Interior Lighting Quality).** Ensure daylighting, artificial lighting and occupant controls to reach best practice in visual performance and comfort for building occupants **(Visual comfort)**					

CATEGORIES	REQUIREMENT	INTENT	BREEAM	LEED	CDA	LAWA	ACRP
	Use alternative and renewable energy sources	Recognise increasing levels of on-site renewable energy self-supply in order to reduce environmental and economic impacts associated with fossil fuel energy use (**On-Site Renewable Energy**) and encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis (**Green Power and Carbon Offsets**)		■	■	■	■
WATER USE	**Landscape and design to reduce water use**	Limit or eliminate the use of potable water, or other natural surface or subsurface water resources available on or near the project site, for landscape irrigation (**Water Efficient Landscaping**)		■	■	■	
	Design for water efficient use: employ water saving devices and/or waterless operating systems	Reduce the consumption of potable water for sanitary use in new buildings from all sources through the use of water efficient components and water recycling systems (**Water Use Reduction**)	■	■	■	■	■
	Design to maximize water harvest, recycle and reuse	Reduce wastewater generation and potable water demand while increasing the local aquifer recharge (**Innovative Wastewater Technologies**) and reclaim and reuse wastewater and storm water to reduce potable water demand and preserve natural water resources **Water Reuse and Reclamation)**		■	■	■	

WASTE & MATERIALS	**Design to provide storage and collection of recyclables**	Recognise and encourage the provision of dedicated storage facilities for a building's operational-related recyclable waste streams, so that this waste is diverted from landfill or incineration **(Storage And Collection Of Recyclables)** and provide infrastructure to recycle on-site waste into beneficial compost for landscaping use **(Provide Infrastructure for Composting & Vermiculture)**					
	Design for deconstruction, reuse and recycling	Determine what design elements and infrastructure are needed to facilitate efficient waste reduction, recycling and reuse during operation **(Construction waste management)** and reduce environmental, economic and social impacts from resource extraction and manufacturing related to future building needs, upgrades and rebuilding on-site by designing structures with modular, reusable, easily recyclable, and de-constructible components **(Design for Deconstruction, Reuse and Recycling)** Create flexible systems, spaces and infrastructure to enhance resource efficiency related to future uses, upgrades and expansions and maximize the life cycle of installed materials **(Flexible Systems, Spaces & Infrastructure/ Functional adaptability)** Recognise and encourage measures to optimise material efficiency in order to minimise environmental impact of material use and waste **(Material efficiency)**					

CATEGORIES	REQUIREMENT	INTENT	BREEAM	LEED	CDA	LAWA	ACRP
	Select recycled, bio-based and rapidly renewable materials	Increase demand for building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials **(Recycled Content)** and reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials **(Rapidly Renewable Materials)**					
	Select materials high design service life, minimizing maintenance and replacement cycles	Recognise and encourage the use of construction materials with a low environmental impact over the full life cycle of the building **(Life cycle impacts/Building Product Disclosure And Optimization)** and direct decisions regarding construction material choices toward maximum practical levels of durability, selecting products with high design service life, extending material life and minimizing maintenance and replacement cycles **(Material Durability)**					
WATER POLLUTION	**Design to reduce stormwater quantity**	Avoid, reduce and delay the discharge of rainfall to public sewers and watercourses, thereby minimising the risk and impact of localised flooding on and off-site **(Rainwater Management)** and minimise site area covered by impervious surfaces in order to reduce runoff and maximise infiltration **(Minimise impervious areas)**					

	Design to improve stormwater quality	Reduce or eliminate stormwater pollution by treating and infiltrating stormwater on-site **(Provide Stormwater Treatment)**					
	Design to protect wetlands and surface water	Limit rate of peak stormwater flows from project site to prevent erosion of downstream properties **(Prevent Downstream Erosion)**					
BIODIVERITY & LAND USE	**Design the layout of infrastructure to avoid destruction of sensitive habitats**	Promote the preservation of undeveloped land by prioritizing and making efficient use of existing infrastructure, rehabilitating contaminated sites, and protecting land for future aeronautical use **(Sustainable Site Selection/Site Assessment)**					
	Design infrastructure and buildings not to be attractive to some species	Promote the preservation, creation, and restoration of ecologically sensitive lands and biodiversity **(Wildlife & Habitat Protection)**					
	Landscape and design to minimise land use and reduce heat island effect	Reduce heat islands to minimize impact on microclimate and human and wildlife habitat **(Landscape and Exterior Design to Reduce Heat Islands)**					
	Design and technologies to reduce light pollution	Promote the efficient management of illumination at night, reducing resource consumption and improving conditions at nearby residential communities **(Light Pollution)**					

The review of existing reporting and rating systems, identification and combining of categories, and identification of gaps allowed the generation of a preliminary list of requirements. The list has been refined through considerations on the specific evaluation criteria and their relevance to airport design. Sustainability activities 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 activities have been grouped to prepare a consolidated set of sustainability requirements. This approach is meant to 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.

Requirements and evaluation criteria have been grouped based on their applicability and efficiency pursuing a specific objective allowing the definition of a set of 22 final requirements which contain a broad range of architectural and technological strategies that would allow an airport to pursue multiple options and pick the ones that best fit their unique situation while progressing toward the goal of improved environmental sustainability. The GrADE categories and sheets associated to those requirements (Table II.4.15) are illustrated in Chapter 6.

Table II.4.15_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

Chapter II.5 – Survey: the role of architectural design in airport environmental sustainability

For the purpose of this research it was a key stage to conduct an extensive experts and operators outreach effort to solicit targeted input from airport industry representatives. A more structured approach with airport managers and planners was necessary in order to obtain a specific feedback regarding the environmental issues constraining airports growth and the design requirements to minimise those impacts.
The purpose of the survey was to gain answers and opinions from representative sample of participants on the process of evaluation of the priorities among a set of architectural design and technological strategies to minimise environmental impacts arising from airport infrastructure development and operations.
The survey was developed using the categories and requirements defined in the previous stages of the research (see Chapter 4, Table II.4.15).

II.5.1_Survey structure

The structured survey contained 28 close-ended questions in total. The set of questions was agreed through discussion with the research supervisors. The survey was self-administrated via *SurveyMonkey*, an online survey development cloud-based ("software as a service") company.

The survey was composed of three parts:

1) Respondent and airport profile;
2) "Airport Environmental Sustainability" – Perception of the issues;
3) "Sustainability Evaluation" – Evaluating strategies for green airport design.

In the first part respondents were asked to provide their contact data and professional profile, and information about the airport they are currently working in. As regard the airport, information were asked regarding the number of passengers forecasted and the infrastructure future development with a specification of the facilities that are planned to be modified (e.g. upgrade, refurbishment, new construction, expansion) over the short (by 2020), medium (by 2030) and long-term (by 2050) period. Those time limits were chosen based on the current data available in most of international and European forecasts regarding the number of passenger growth, but also –for example – the projected levels of emissions (i.e. noise, carbon and other green house gas emissions), the use of energy, the water consumption, etc.
The second part focused on the perception of environmental issues and the specification of those impacts that are currently constraining the airport growth or are foreseen as a threat for the future expansion. Moreover, some specific questions were provided regarding green building rating systems and the environmental certifications pursued by airport operators. Respondents were asked to answer some multiple-choice questions and assign values regarding the proposed issues.

The last part was structured on the basis of the issues defined at the end of Chapter 4, which represent the main environmental issues arising from airport expansion and operations, namely biodiversity and habitat preservation, carbon emissions and air quality, energy use, noise, waste and materials, water pollution, and water use. For each issue two questions have been proposed.
The first one – common to all issues – asked to assign a level of importance (from 1, not important to 5, very important) to the three main strategies to reduce environmental issues:

- Operations management, which refers to operativity of the infrastructure and the aircraft and other airport means operations;
- Technical equipment, which attain the technology of the service equipment (aircraft engine and design, APU systems, GSE, etc.);
- Architectural design, which is related to the infrastructure project design (airport layout, terminal and buildins design, etc.) and technological strategies (materials, systems, components).

Each issue analysed through the survey correspond to a category of the final GrADE framework (see Chaprter 6).
The second question was specific for each issue and provided a list of options (architectural design strategies) to minimise that issue. Respondents were asked to assign a level of importance (from 1, not important to 5, very important) to those options. Each option provided in the survey, represent a requirement/sheet of the final GrADE framework (see Chaprter 6).

II.5.2_Respondent selection and feedbacks

The survey was addressed to the airport managers of the planning, infrastructure development, environmental, and technical divisions of the European air transport network. By participating, they provided a structured and competent support as regard the good practices for the sustainable airport infrastructure planning and design.
To select the participants a list of European airports was defined. The list included the civil (commercial) international airports with more than 1 million passengers per year (registered at least in one of the last 5 years). A total of 213 airports were identified to participate. Contacts were selected from those airports within the technical, environment, planning and development divisions. At the end of the process 125 participants from 33 countries were selected. Participants were contacted by e-mail. A presentation letter with the link to the survey was sent to the list of selected contacts. In case wasn't possible to find a direct e-mail contact, an e-mail was sent to the general 'info mail' of the airport or to the airport operator or a message was sent through the LinkedIn profile.
During the 6-week data-collection period, two reminder e-mails were sent to respondents who had not yet completed the survey in order to enhance the response rate.

II.5.3_Analysis of collected data

At the close of the survey, responses were collected from 21 participants/airports corresponding to a 17 percent response rate. The participants represented a wide range of European countries (14 in total), namely Albania, Austria, Bulgaria, Denmarck, Estonia, France, Germany, Greece, Ireland, Italy, Norway, Switzerland, and United Kingdom. Most of participants are engineers and environmental specialists and work as Head of planning department, planning Post Holder or environmental department Managers. Following the complete list of participating airports:

- Tirana Airport (Albania)
- Salzburg Airport (Austria)
- Sofia Airport (Bulgaria)
- Billund Airport (Denmark)
- Copenhagen Airport (Denmark)
- Tallin Airport (Estonia)
- Aéroports de Paris (France)
- Cologne Airport (Germany)
- Frankfurt Airport (Germany)
- Athens Airport (Greece)
- Bologna Airport (Italy)
- Cagliari Airport (Italy)
- Torino Airport (Italy)
- Venice Airport (Italy)
- Verona Airport (Italy)
- Cork Airport (Ireland)
- Bergen Airport (Norway)
- Oslo Airport (Norway)
- Belfast Airport (United Kingdom)
- Gatwick Airport (United Kingdom)
- Zurich Airport (Switzerland)

After receiving the first-round of filled surveys and analysing the answers, participants were asked to check some of their responses and confirm them. In fact, it was noticed that as regard some questions there wasn't a common opinion on the value to assign to the suggested options. A set of tables was arranged collecting the number of respondents who assigned a certain value to each options.
For example, as shown in the Table II.5.1, at the option “Biodiversity and Habitat preservation”, 1 person assigned value “1”, 6 people assigned value “2”, and so on (see the boxes highlighted in yellow). This feedback did not allowed the evaluation of the preferred option and therefore to assign a value to the proposed options. On the contrary, for the option “Water pollution” a high percentage of answers was concentrated around values “4” and “5” (see the boxes highlighted in green).
The “Final value” is based on the “Percentage on the total” of the first two higher answers associated to an option. For example, as regard the option “Energy use” (see the boxes highlighted in red), there are 9 people who assigned value “4” and 9 people who assigned value “5” for a total of 18 people representing the 86% of total answers for that option. So the final value for energy use is 4.5.

Table II.5.1_ Exemplificative excerpt of a first-round set of answers. Each row indicates the number of answers assigned to each value (from 1 to 5) for each environmental issue ('Answer Options') on the total number of the answers received

Answer Options	1	2	3	4	5	Final value	Percentage on the total
Biodiversity and Habitat preservation	1	6	5	5	4	2.5	52%
Carbon emissions reduction and Air quality	1	2	4	6	8	4.5	67%
Energy use	0	1	2	9	9	4.5	86%
Noise abatement	0	1	1	4	15	5	90%
Waste management and Use of materials	0	4	5	9	3	3.5	67%
Water pollution	1	2	1	10	7	4.5	81%
Water use	4	7	4	3	3	2	62%

The participants were provided with information regarding the analysis of the first-round set of answers and were asked their opinion regarding the outcomes and to review or confirm their own answers. After the second-round of the survey, twelve participants answered. It has been noticed that in most cases participants confirmed their choices, but it was significant the feedback for those options that had resulted more critical – because of the dispersion of opinion. The second-round – that was also characterised by a direct contact with the participants who have been interviewed over skype or via phone – brought to the attention the limits of the questions and the need to clarify the content and meaning of some options. At the end of this process, a more clear evaluation of the answers was possible as shown in the following paragraphs..

II.5.3.1 Airport growth

Half of the airports represented in this survey registered less than 5 million passengers in 2014. One third of the airports registered more than 15 million passengers (two of them registered more than 50 million). The remaining 20% of airports registered a number of passengers between 5 and 10 million.
Most of airports (Fig. II.5.1) will remain between 5 and 20 million number of passengers in the short-term period (2020). This tendency remain almost constant in the medium (2030) and long-term period (2050).

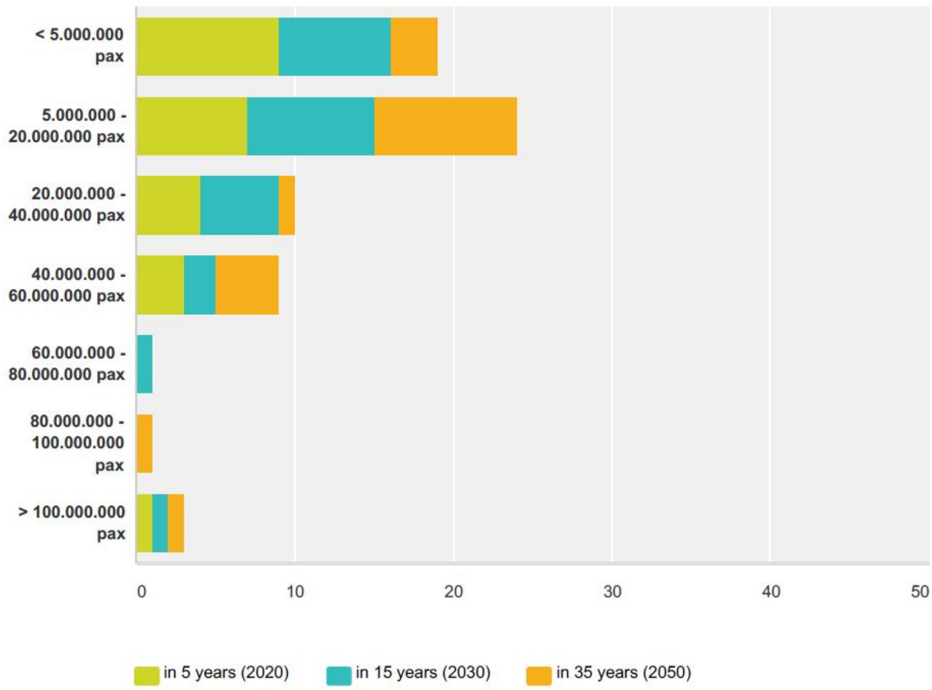


Figure II.5.1 – Graphic representing number of answers for each option representing different number of passengers range in the short, medium and long-term period

It has been noticed that the change in the rate of passengers correspond to a planning modification of airport facilities (Fig. II.5.2). In the short term most of the intervention will regard parking lots facilities, terminal buildings, and systems and facilities for alternative and renewable energy production. On the other hand, in the medium-term period most of planning development and refurbishing regard rail/metro station serving the airport and the construction of other building facilities (such as office, hotels, conference centres, *etc.*). This response represents the need of an integration with the urban and regional transport system and the tendency for airports to become attractors to other activities which can have benefit from the proximity to the infrastructure. A model that assumes different names and structure – airport city, airport corridor, airport region – and that in any case represents a urban development pattern that in Europe can develop thanks to the network of infrastructure (road, rail, ports) which can ease the integrated and sustainable mobility.
There aren't significant modification in the long-term period, but this response could also depend on the fact that most of the smaller airports don't have a detailed plan for the horizon 2050 or – when they have it – it is more reliant on the governance and the political strategy of the surrounding regions within the country or, on a broader level, within Europe.

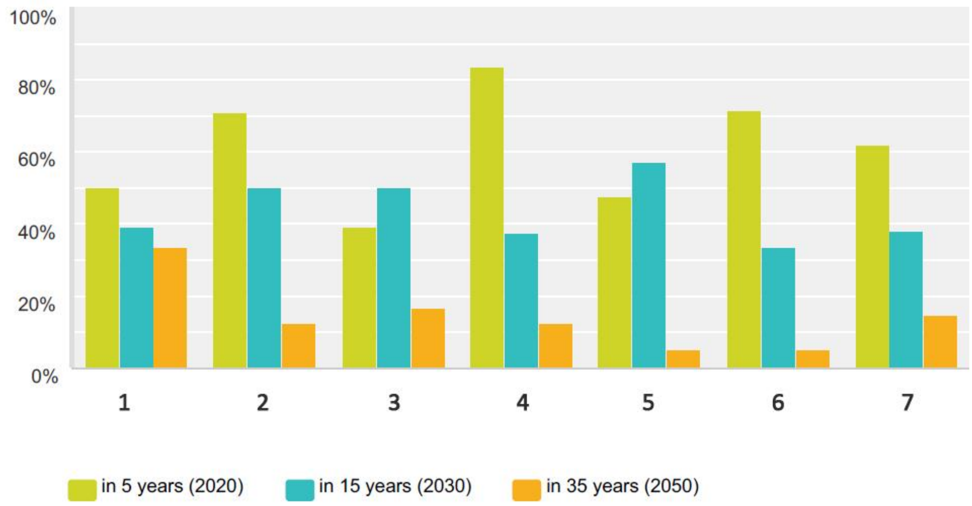


Figure II.5.2 – Graphic representing number of answers for each option representing different parts of the infrastructure which will be modified in the short, medium and long-term period. Option 1)Runway/s; 2) Terminal building/s; 3) Rail/metro station; 4) Parking lots; 5) Other building facilities (e.g. office, hotels, conference centres, etc.); 6) Systems and facilities for alternative and renewable energy production; 7) Systems and facilities for water harvesting and treatment

II.5.3.2 Sustainability and environmental constraints

The concept of sustainability include different aspects. For the purpose of this research only environmental sustainability have been explored, but the author acknowledge the fact that in order to be effective the definition and evaluation of sustainable airport development should also consider aspects such as operational capacity, business viability, and community needs. The participants' answers (Fig. II.5.3) show how important are all these aspects. It is evident that almost the same value is assigned to all the suggested options showing a slightly more relevance regarding environment protection and use of resources and less as regard community.

Environmental issues are in fact considered as a threat to the airport future growth for the majority of respondents (60 percent of them answered 'Yes' as shown in Fig. II.5.4). It has been noticed that the negative answer in this case is in the most cases associated with airports that are facing small or no expansion or that have already adopted effective strategies to reduce the magnitude of the environmental impacts.

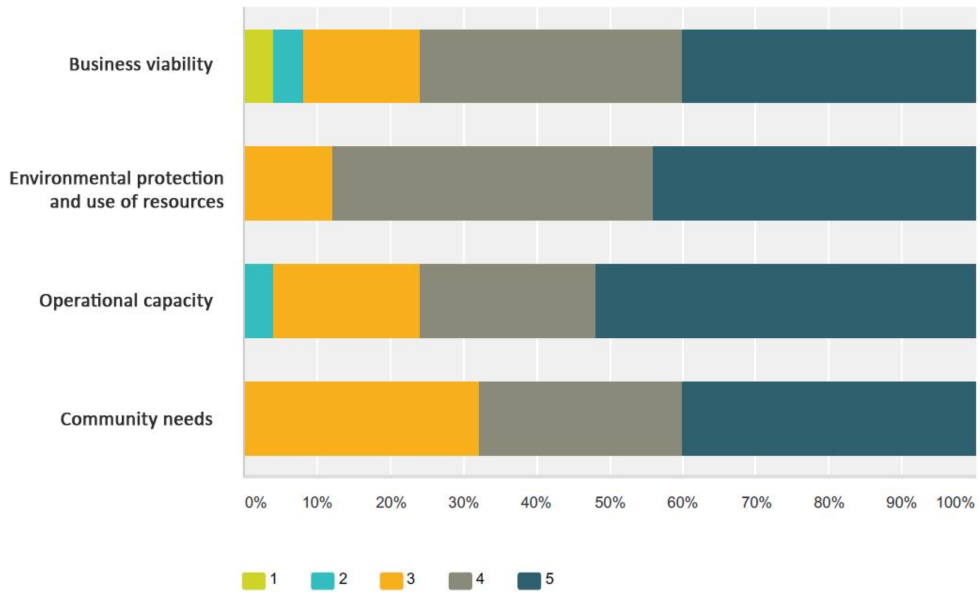


Figure II.5.3 – Graphic representing percentage of values assigned to each option representing different aspects of sustainability. Values from 1 to 5, where 1 means that is not important and 5 means that is extremely important

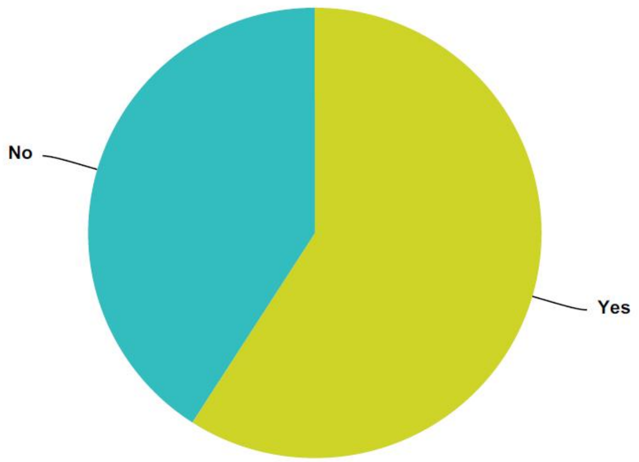


Figure II.5.4 – Graphic representing percentage of answer regarding the perception of environmental issues as a threat to the airport future growth

For the purpose of this research, the questions focused on the environmental issues. Participants when asked what environmental issues are currently constraining airport growth and what will constraint the growth in the medium-term period (15 years), which have been chose as a term to properly evaluate the strategies that airports are currently developing for the airport future expansion and operations increase (Figg. II.5.5 and II.5.6).

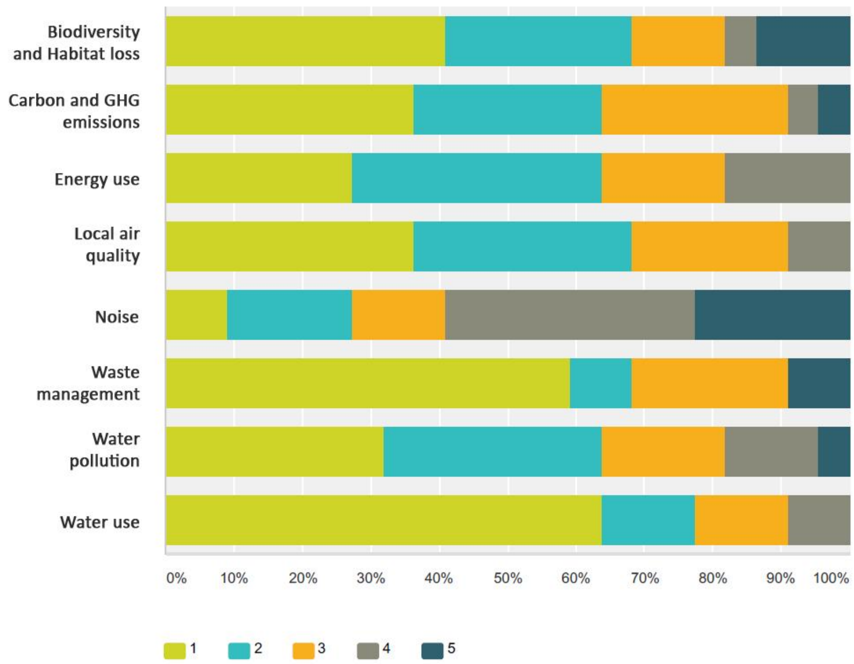


Figure II.5.5 – Graphic representing percentage of answers for each option representing different environmental issues (as suggested in Chapter 4) which are currently constraining airport growth. Respondents were asked to assigne a value from 1 to 5 where 1 means that it represent a very low level of constraint and 5 that it represent a very high level of constraint

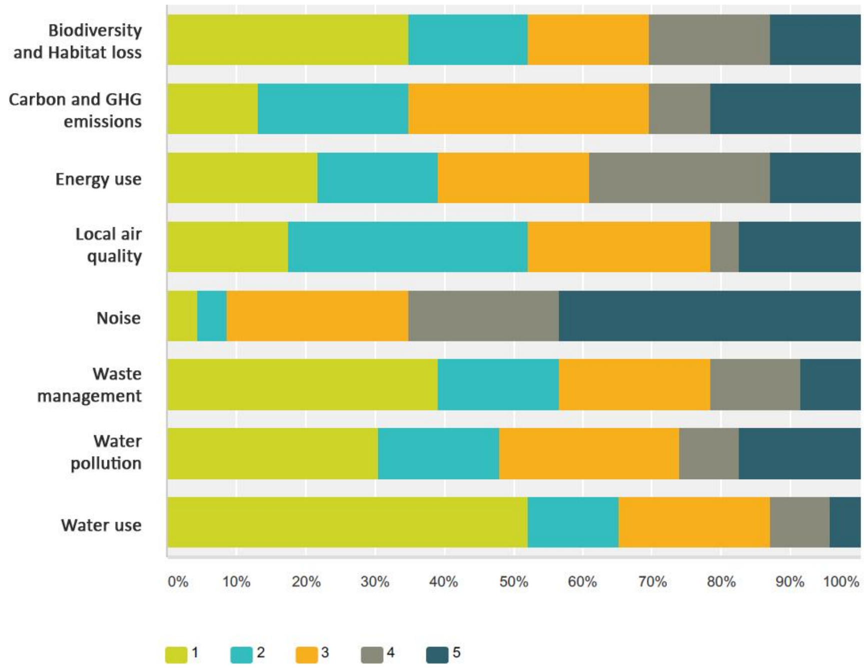


Figure II.5.6 – Graphic representing percentage of answers for each option representing different environmental issues (as suggested in Chapter 4) which are foreseen to constrain airport growth in the medium-term period.

The two graphics show how noise represent a threat for airport growth over the time. On the contrary, a low value is assigned to water use.
It is interesting to notice the change in the value assigned to local air quality, carbon emissions and energy use: the answers illustrate that they don't seem to currently represent a constraint for the majority of airports, but this trend changes over the 15-year time period when they are perceived more as a threat also with water pollution issue. From the analysis of the strategies adopted from the participant airports, it can be noticed that even if many airports have developed strategies to reduce the magnitude of those impact, the forecasted future growth in the operations and the needed expansion of the infrastructure will ask for more effective strategies to maintain the percentage of emissions (i.e. carbon, greenhouse gasses, noise) under certain levels (e.g. baseline or benchmark).

II.5.3.3 Sustainability and environmental constraints

Following the general evaluation of the environmental issues that are currently constraining European airports, respondent were asked a more specific opinion based on the selection and the level of priority allocation of the architectural and technological strategies aimed at minimising the environmental impacts.
When asked to assign a level of priority to the proposed issues/categories (Fig. II.5.7), the answers mirrored the perception of environmental issues as a threat as shown in Fig. II.5.6 . From the graphic below it is evident that noise abatement, energy use and waste management represent the categories with an higher priority level. Followed by water pollution, carbon emissions reduction and air quality enhancement, biodiversity and habitat preservation, and water use.

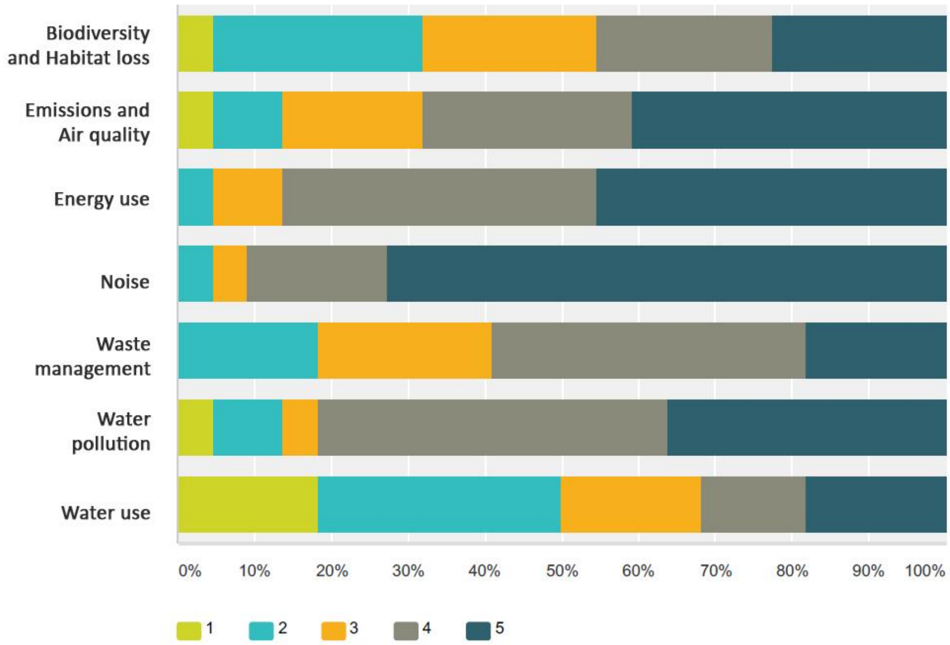


Figure II.5.7 – Graphic representing percentage of answers for each option representing different environmental issues/categories

After receiving and analysing the second-round set of answers (Tab. II.5.2), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.2 – Number of answers assigned to each value (from 1 to 5) for each environmental issue('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	**1**	**2**	**3**	**4**	**5**	**Response Count**
Biodiversity and Habitat preservation	0	8	7	6	0	21
Carbon emissions reduction and Air quality	0	1	3	9	8	21
Energy use	0	0	2	10	9	21
Noise abatement	0	0	1	3	17	21
Waste management and Use of materials	0	2	8	9	2	21
Water pollution	0	1	1	11	8	21
Water use	6	11	3	1	0	21

Based on this analysis the following weights were assigned to each environmental issues which represent the seven categories of the GrADE framework (see Chapter 6):

- Biodiversity and Habitat preservation 19%
- Carbon emissions reduction and Air quality 17%
- Energy use 17%
- Noise abatement 6%
- Waste management and Use of materials 14%
- Water pollution 17%
- Water use 10%

In the following sections, the final values associated to each of the categories proposed (i.e. noise emissions, carbon and greenhouse gas emissions and air quality, water pollution, energy use, water use, waste generation, biodiversity and habitat) are illustrated.

Noise emissions

When asked to assign a value of importance to the suggested three main strategies to minimise noise emissions (Fig. II.5.8), respondents evaluated as ‘operations management’ as the most significant as it relates to the operational procedures and the regulations that airports have to comply with in order to function. The second choices was ‘technical equipment’ that in this case mostly relates to the aircrafts. Even if they are the main source of noise in airports, their renovation is related to the technology advancements and to the period for testing those technologies in order to be used. Therefore, this option is seen as less applicable then the first even if it would be more effective. ‘Architectural design’ has a marginal role in the abatement of noise disturbance as in Europe the lack of land for infrastructure make difficult to apply some specific strategies (such as Design airside layout to reduce noise emissions). Those strategies would be in any case less effective during the take-off and landing of aircraft.

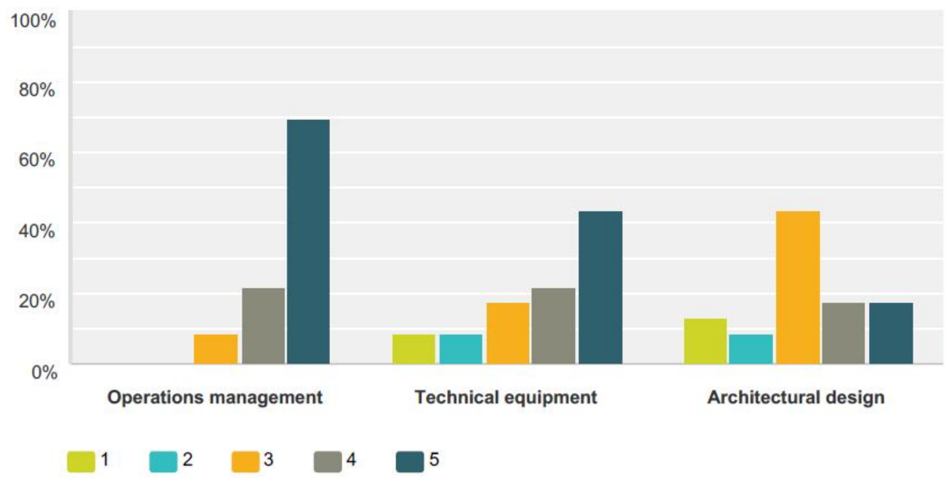


Figure II.5.8 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to the noise abatement

When asked to evaluate the specific architectural and design strategies to mitigate the effects of noise emissions, participants assigned a similar value to both the options proposed (Fig. II.5.9).

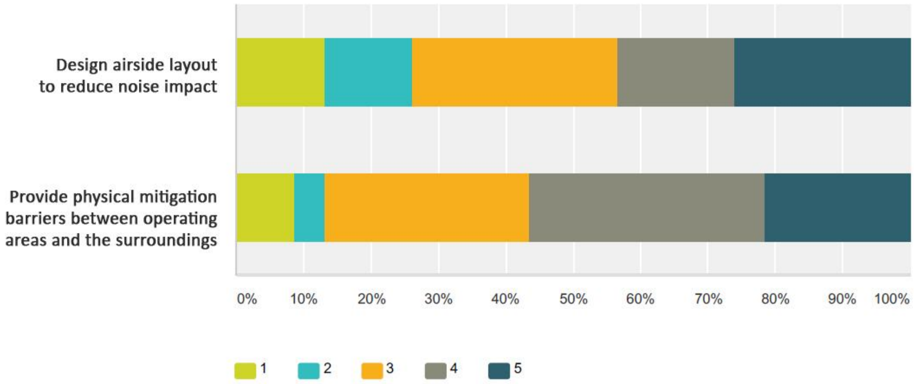


Figure II.5.9 – Graphic representing percentage of answers for each option related to design strategies for the minimisation of noise disturbance

After receiving and analysing the second-round set of answers (Tab. II.5.3), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.3 – Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	**1**	**2**	**3**	**4**	**5**	**Response Count**
Design airside layout to reduce noise impact	0	1	12	6	2	21
Provide physical mitigation barriers between operating areas and the surroundings	1	1	8	10	1	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Design airside layout to reduce noise impact 50%
- Provide physical mitigation barriers between operating areas and the surroundings 50%

Carbon and greenhouse gas emissions and air quality

When asked to assign a value of importance to the suggested three main strategies to minimise carbon and other gas emissions and enhance air quality (Fig. II.5.10), respondents evaluated as 'operations management' and 'technical equipment' as the most significant. These two options are in fact closely related as the technology of the aircrafts may affect the opportunities to change operations pattern in order to reduce the emissions.
'Architectural design' has a marginal role in the abatement of gaseous emissions if compared to the other two options. As in the case of noise abatement, architectural strategies would greatly be affected by the specific regulation related to airport operations and therefore it represent a limited field of action for the purpose of emissions abatement.

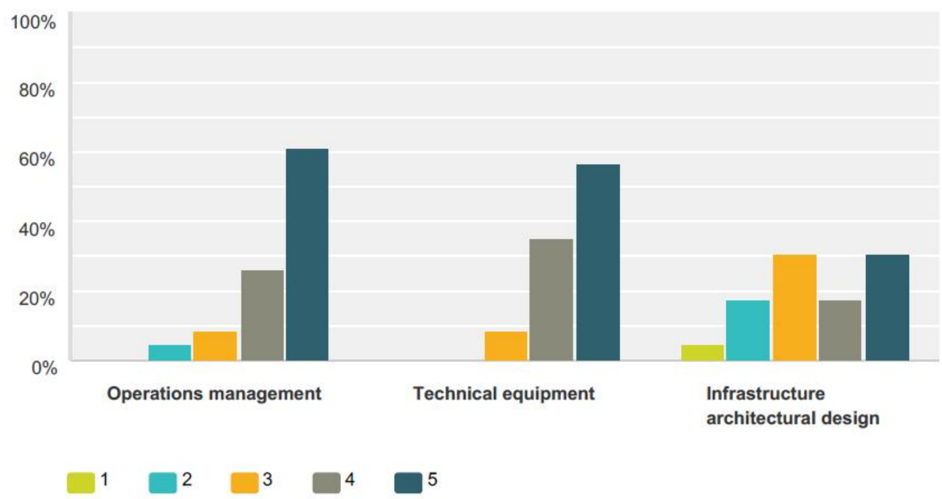


Figure II.5.10 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to carbon and greenhouse gas emissions and the air quality

When asked to evaluate the specific architectural and design strategies to reduce gaseous emissions and improve air quality, participants assigned a similar value to the options related to the development of public transport and to the design of the overall infrastructure (Fig. II.5.10). A lower value was assigned to the design of the airside layout and the reduction of parking footprint.

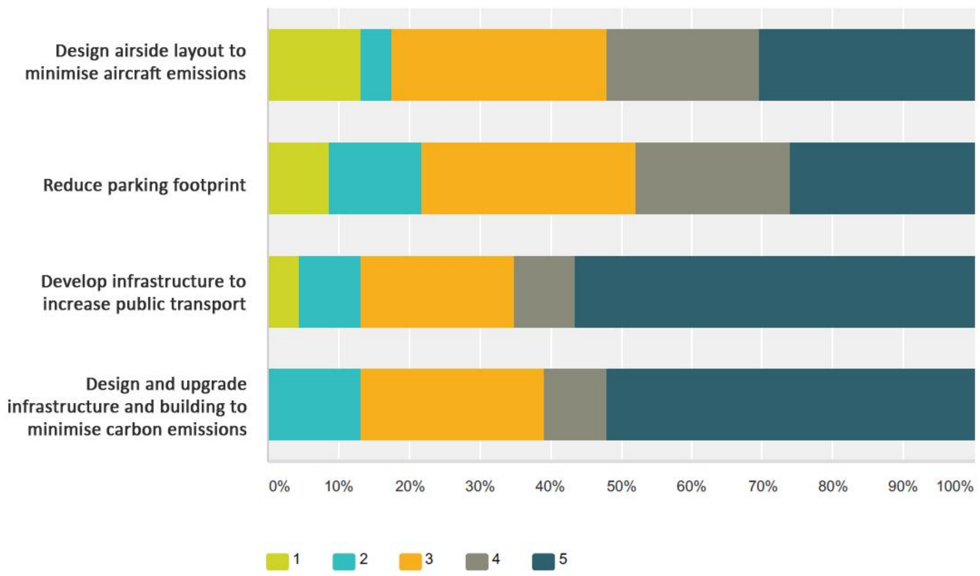


Figure II.5.11 – Graphic representing percentage of answers for each option related to design strategies for the minimisation of gas emissions and the enhancement of air quality

After receiving and analysing the second-round set of answers (Tab. II.5.4), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.4– Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	**1**	**2**	**3**	**4**	**5**	**Response Count**
Design airside layout to minimise aircraft emissions	0	1	10	8	2	21
Reduce parking footprint	1	3	9	7	1	21
Develop infrastructure to increase public transport	1	1	2	6	11	21
Design and upgrade infrastructure and buildings to minimise carbon emissions	0	2	2	7	10	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Design airside layout to minimise aircraft emissions 22%
- Reduce parking footprint 22%
- Develop infrastructure to increase public transport 28%
- Design and upgrade infrastructure and buildings to minimise carbon emissions 28%

<u>Water pollution</u>

When asked to assign a value of importance to the suggested three main strategies to reduce the risks of water pollution (Fig. II.5.12), respondents gave a similar evaluation to the options with a slight preference to the 'technical equipment' that in this case also represents the set of maintenance vehicles and equipment and the system for collecting ans treating water.

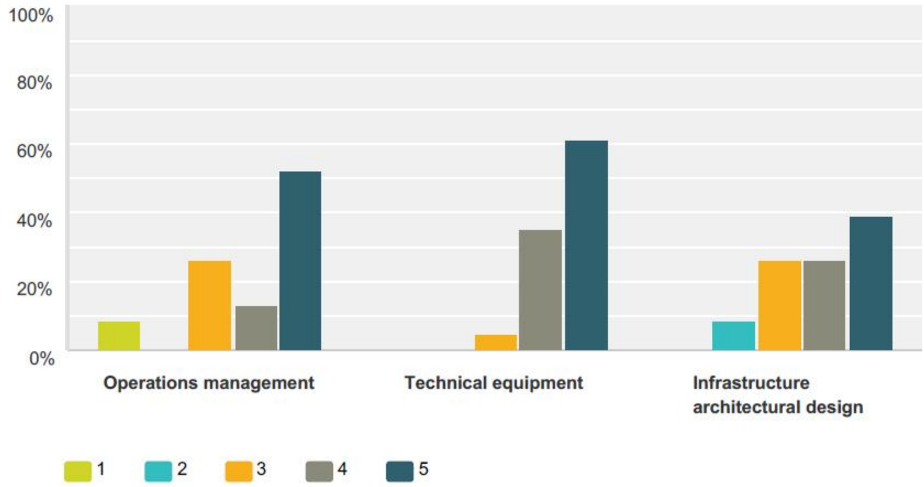


Figure II.5.12 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to water pollution

When asked to evaluate the specific architectural and design strategies to reduce water pollution, participants assigned a similar value to the options related to the design for reducing both stormwater quantity and quality (Fig. II.5.13). Both aspects in fact represent a risk not only for the aquifer but for the security of the infrastructure (respectively in case of floods and of water reuse).

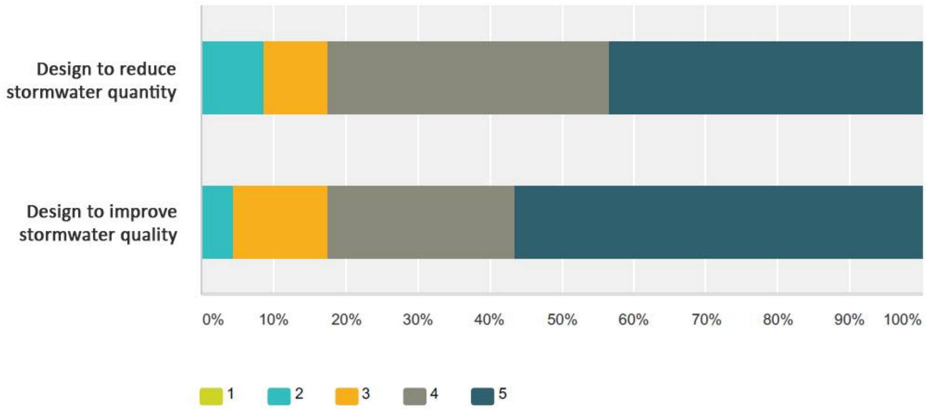


Figure II.5.13 – Graphic representing percentage of answers for each option related to design strategies to reduce and avoid water pollution

After receiving and analysing the second-round set of answers (Tab. II.5.5), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.5 – Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	1	2	3	4	5	Response Count
Design to reduce stormwater quantity	0	1	1	10	9	21
Design to improve stormwater quality	0	1	2	7	11	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Design to reduce stormwater quantity 50%
- Design to improve stormwater quality 50%

Energy use

When asked to assign a value of importance to the suggested three main strategies to reduce the impacts related to energy use (Fig. II.5.14), respondents assigned the higher evaluation to ‘technical equipment’ and ‘architectural design’, while ‘operations management’ was considered less effective.

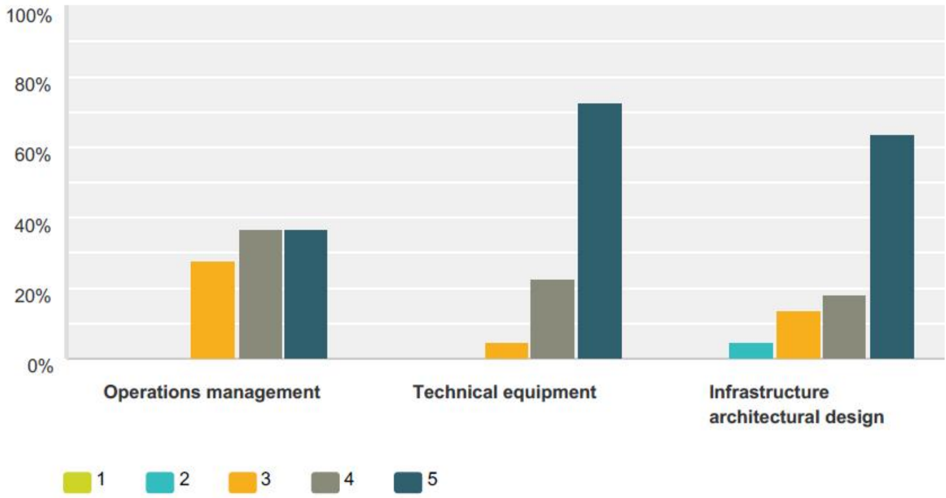


Figure II.5.14 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to the energy use

When asked to evaluate the specific architectural and design strategies to reduce the impact of energy use, participants assigned a similar value to the proposed options (Fig. II.5.15).

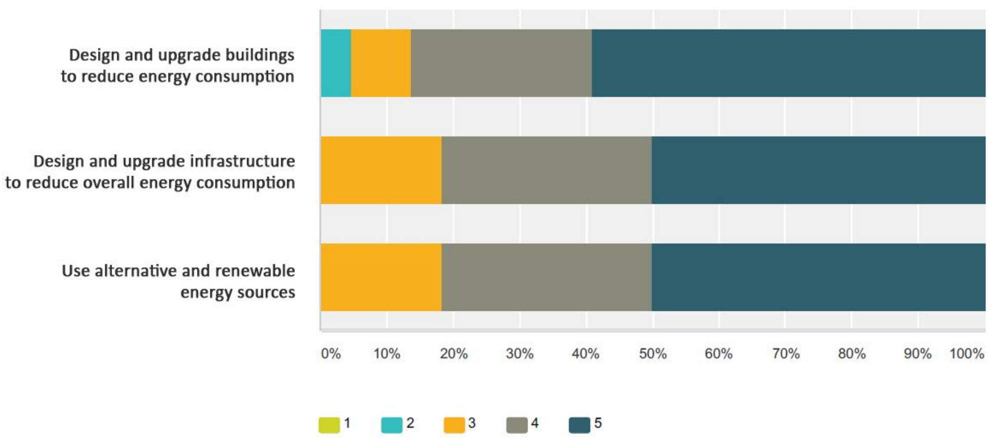


Figure II.5.15 – Graphic representing percentage of answers for each option related to design strategies to energy use

After receiving and analysing the second-round set of answers (Tab. II.5.6), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.6 – Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	1	2	3	4	5	Response Count
Design and upgrade buildings to reduce energy consumption	0	1	2	3	15	21
Design and upgrade infrastructure to reduce overall airport energy consumption	0	0	4	7	10	21
Use alternative and renewable energy sources	0	0	3	8	10	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Design and upgrade buildings to reduce energy consumption 36%
- Design and upgrade infrastructure to reduce overall airport energy consumption 32%
- Use alternative and renewable energy sources 32%

Water use

When asked to assign a value of importance to the suggested three main strategies to reduce the impacts related to water use (Fig. II.5.16), respondents assigned the higher evaluation to 'technical equipment' and a similar evaluation to the other two options. Compared to the other questions, it has been noticed that this category received the lowest evaluation rates. This tendency is in fact in line with the value that participant assigned to the 'water use category' as showed at the beginning of paragraph II.5.3.3. As in the case of 'water pollution', in this section 'technical equipment' represents the set of maintenance vehicles and equipment and the system for collecting and treating water which therefore highly affect the opportunity to use efficiently and reuse water ('architectural design') and may limit the operational capacity of the infrastructure ('operations management') when they fail to ensure the compliance with the related regulatory framework.

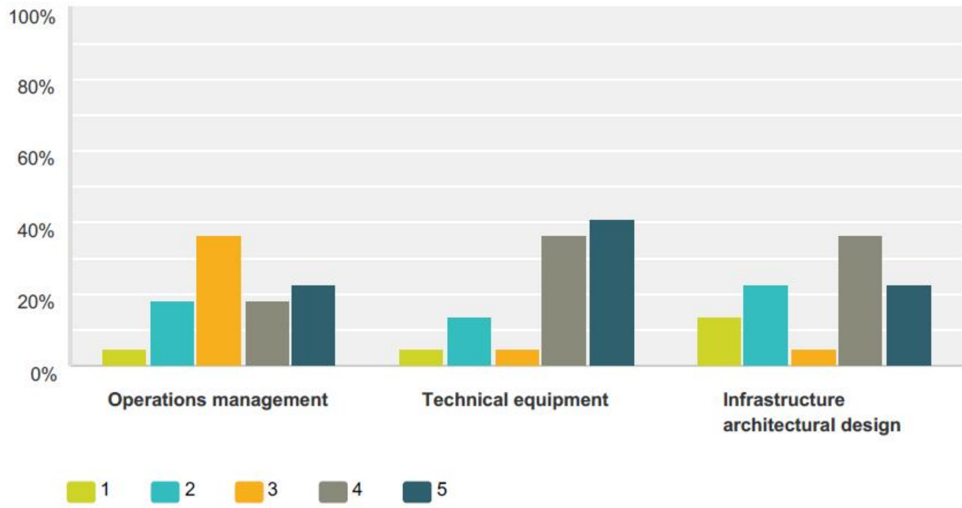


Figure II.5.16 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to water use

When asked to evaluate the specific architectural and design strategies to reduce the impact of water use, participants assigned a similar value to the proposed options (Fig. II.5.17).

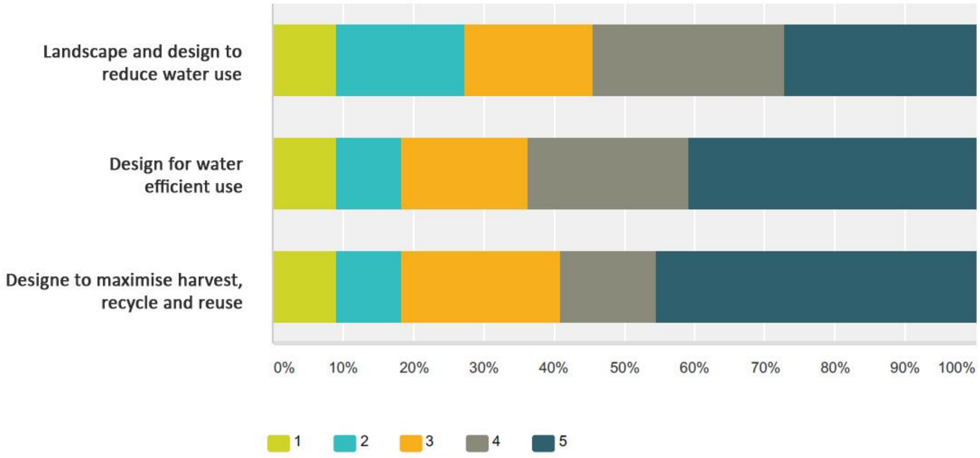


Figure II.5.17 – Graphic representing percentage of answers for each option related to design strategies to water use

After receiving and analysing the second-round set of answers (Tab. II.5.7), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.7 – Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	1	2	3	4	5	Response Count
Landscape and design to reduce water use	0	2	7	9	3	21
Design for water efficient use	1	1	2	7	10	21
Design to maximize water harvest, recycle and reuse	0	2	2	6	11	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Landscape and design to reduce water use 28%
- Design for water efficient use 36%
- Design to maximize water harvest, recycle and reuse 36%

<u>Waste generation</u>

When asked to assign a value of importance to the suggested three main strategies to minimise the impacts related to the waste generation (Fig. II.5.18), respondents assigned the higher evaluation to 'operations management' which is in fact the main source of waste generation and ghave an impact on the general management of wastes (storage, disposal, etc.).

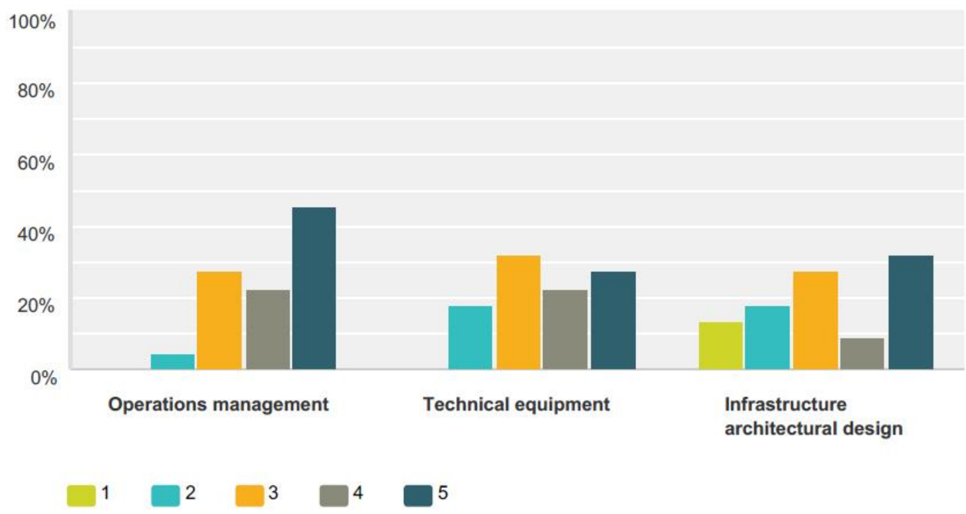


Figure II.5.18 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to waste generation

When asked to evaluate the specific architectural and design strategies to reduce the impact of waste generation, participants assigned the higher value to the design for the storage and collection of recyclables (Fig. II.5.17). In fact this option is strictly connected both to the management of airport operations in term of waste management and to the technical equipment needed to provide those services and support operations. A slightly lower value was assigned to the design for deconstruction that represent an important aspect in particular in the design of terminal building which need to be flexible to change of passenger typology and flow and easily upgradeable. A similar value was assigned to the selection of materials with reference to their service life, while the lower value was assigned to the selection of recycled, bio-based and rapidly renewable materials.

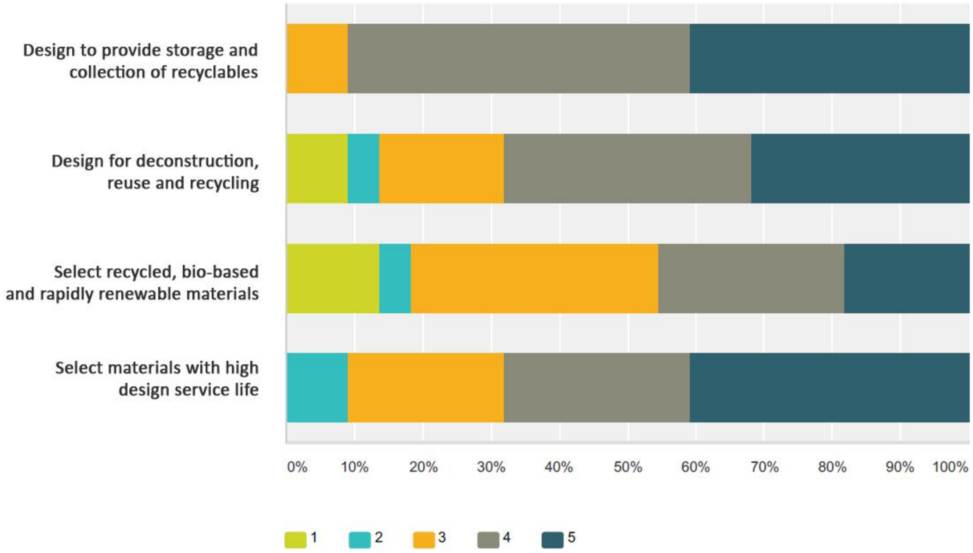


Figure II.5.19 – Graphic representing percentage of answers for each option related to design strategies to waste generation

After receiving and analysing the second-round set of answers (Tab. II.5.8), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.8 – Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	1	2	3	4	5	Response Count
Design to provide storage and collection of recyclables	0	0	2	11	8	21
Design for deconstruction, reuse and recycling	0	1	2	10	8	21
Select recycled, bio-based and rapidly renewable materials	1	1	10	8	1	21
Select materials with high design service life	0	1	3	8	9	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Design to provide storage and collection of recyclables 26%
- Design for deconstruction, reuse and recycling 26%
- Select recycled, bio-based and rapidly renewable materials 22%
- Select materials with high design service life, minimising maintenance and replacement cycles 26%

Biodiversity and habitat

When asked to assign a value of importance to the suggested three main strategies to preserve biodiversity and habitat (Fig. II.5.20), respondents assigned the higher evaluation to 'architectural design' as it has the higher impact on the opportunities to reduce the impact of airport new construction and/or development with a set of strategies that go from the urban design (configuration of infrastructure layout) to the technological level (selection of materials and component which may improve the ecological quality of the building environment).
The lowest value was assigned to the 'technical equipment', while it was considered more important the 'operations management as a great impact derive from the proximity of certain species of animals on the aircraft operations.

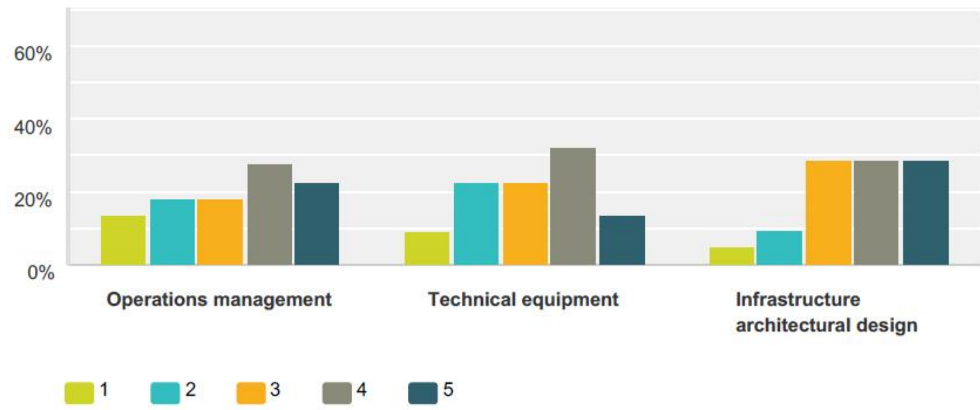


Figure II.5.20 – Graphic representing percentage of answers for each option representing the three main strategies to reduce environmental issues in relation to biodiversity and habitat preservation

When asked to evaluate the specific architectural and design strategies to preserve biodiversity and habitat, participants assigned the higher value to the design of the airport layout and of the buildings (Fig. II.5.21). on the other hand the options related to the heat island effect and the light pollution collected a lower value as they are more related to the regulations which prescribe specific performances to the materials used (in particular for the aircrafts' parking slots pavements) and to the lighting system (which guarantee the safety and security of aircraft operations on-site and during the take-off and landing procedures).

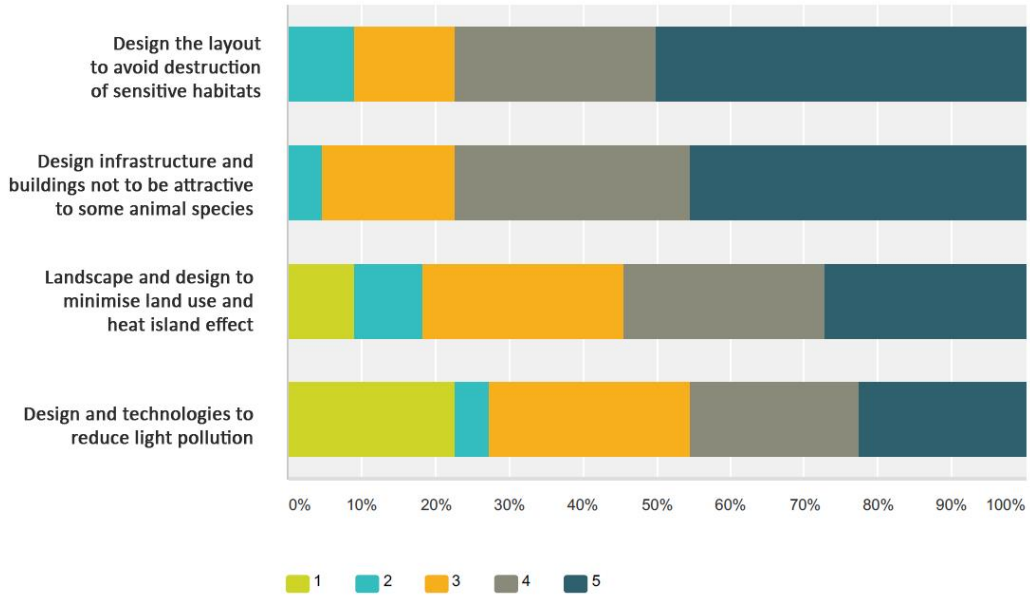


Figure II.5.21 – Graphic representing percentage of answers for each option related to design strategies to biodiversity and habitat preservation

After receiving and analysing the second-round set of answers (Tab. II.5.9), the final value was associated to each environmental issue and converted in a percentage weight on the total (100%).

Table II.5.9 – Number of answers assigned to each value (from 1 to 5) for each design strategy ('Answer Options') on the total number of the answers received ('Response Count')

Answer Options	1	2	3	4	5	Response Count
Design the layout of infrastructure to avoid destruction of sensitive habitats	0	1	2	8	10	21
Design infrastructure and buildings not to be attractive to some animal species	0	0	2	8	11	21
Landscape and design to minimise land use and reduce heat island effect	1	2	7	10	2	21
Design and technologies to reduce light pollution	0	1	11	6	3	21

Based on this analysis the following weights were assigned to each design strategy each one representing a sheet of the GrADE framework (see Chapter 6):

- Design the layout of infrastructure to avoid destruction of sensitive habitats	28%
- Design infrastructure and buildings not to be attractive to some animal species	28%
- Landscape and design to minimise land use and reduce heat island effect	22%
- Design and technologies to reduce light pollution	22%

PART III

GREEN AIRPORT DESIGN EVALUATION (GrADE)

Chapter III.6 – GrADE methods and tools

Although many efforts have been made to define sustainability and green building and to identify 'green airport practices', no broad, industry-adopted system exists to rate airport environmental sustainability performances. The result of this study is the application of environmental sustainability criteria in airport design through the support of an *ad hoc* evaluation framework. 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. This type of project design organisation enables the management of the sustainability requirements and it also ensures the consistent verification of all project levels of development, since the early stage of project conception.
Such system would help airports evaluate continued environmental sustainability performances; set sustainability objectives, and targets; improve internal and external relations; increase their competitive advantage; and help justify sustainability management. The *Green Airport Design Evaluation* (GrADE) model is designed to allow, initially, individual airports to assess and track their sustainability performance internally; however, if desired by the airport community, the framework could also support ratings and comparisons between airports in the future.
The GrADE is based on the following design specifications gleaned from the stakeholder process and from the scientific literature review:

1. incorporate elements of existing rating systems to the extent possible;
2. include a points-based scoring framework;
3. recognise airport-wide sustainability performance;
4. emphasise flexibility to accommodate all airport typology of intervention.

The GrADE reflects the effort to respond to and incorporate the design specifications. Environmental sustainability performance spans airport-wide practices including new construction and existing infrastructure. Sustainability requirements, and their associated performance metrics and strategies, promote actual progress toward sustainability by focusing on the outcome rather than the process or projects completed. This facilitates flexibility, allowing an airport to choose how best to achieve a high level of sustainability performance.

III.6.1_A method for airport environmental sustainability evaluation

The goal of the GrADE methods and tools is to help airports identify, evaluate, prioritise, and select environmental sustainability practices for airport design since the early stages of project conception and development.
The tools consist of a set of sheets that are intended to provide a planning space for users to evaluate strategies and prepare plans that can assist in decision making. The users are represented by the professionals working in the technical division, responsible for the definition of the project design complying with the

requested requirements; the airport managers, who administrate the infrastructure, coordinating all the activities and supervising the design process; the national aviation authority that is in charge of monitoring, control and approval all the decisions and activities of airport managers and operators.

To assist in evaluation and prioritisation, a weight is assigned to each of the issues (categories) and requirements (sheets). 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.
The scoring framework supports the GrADE model by providing a mechanism for establishing a rating. The basic construct of the scoring framework is simple: airports score points for achieving levels of performance within each requirements. Points can be earned and summed for all sustainability activities to gauge airport-wide performance across the GrADE, within each category to gauge performance in sectors, or for a single sustainability activity to target performance in one area.
The GrADE method provides participating airports the flexibility to use the system in the way that best suits their needs and resources without requiring high performance across all requirements. 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 implementing a complete set of requirements within a category or even the entire GrADE system.

Withint 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.
Each category contains a different number of requirements and design specifications (Tab. III.6.1). Each requirement is included in a sheet that provides with information regarding: the purpose and definition of the requirement, architectural and technological strategies for the minimisation of the environmental impacts, specific standards and regulations.

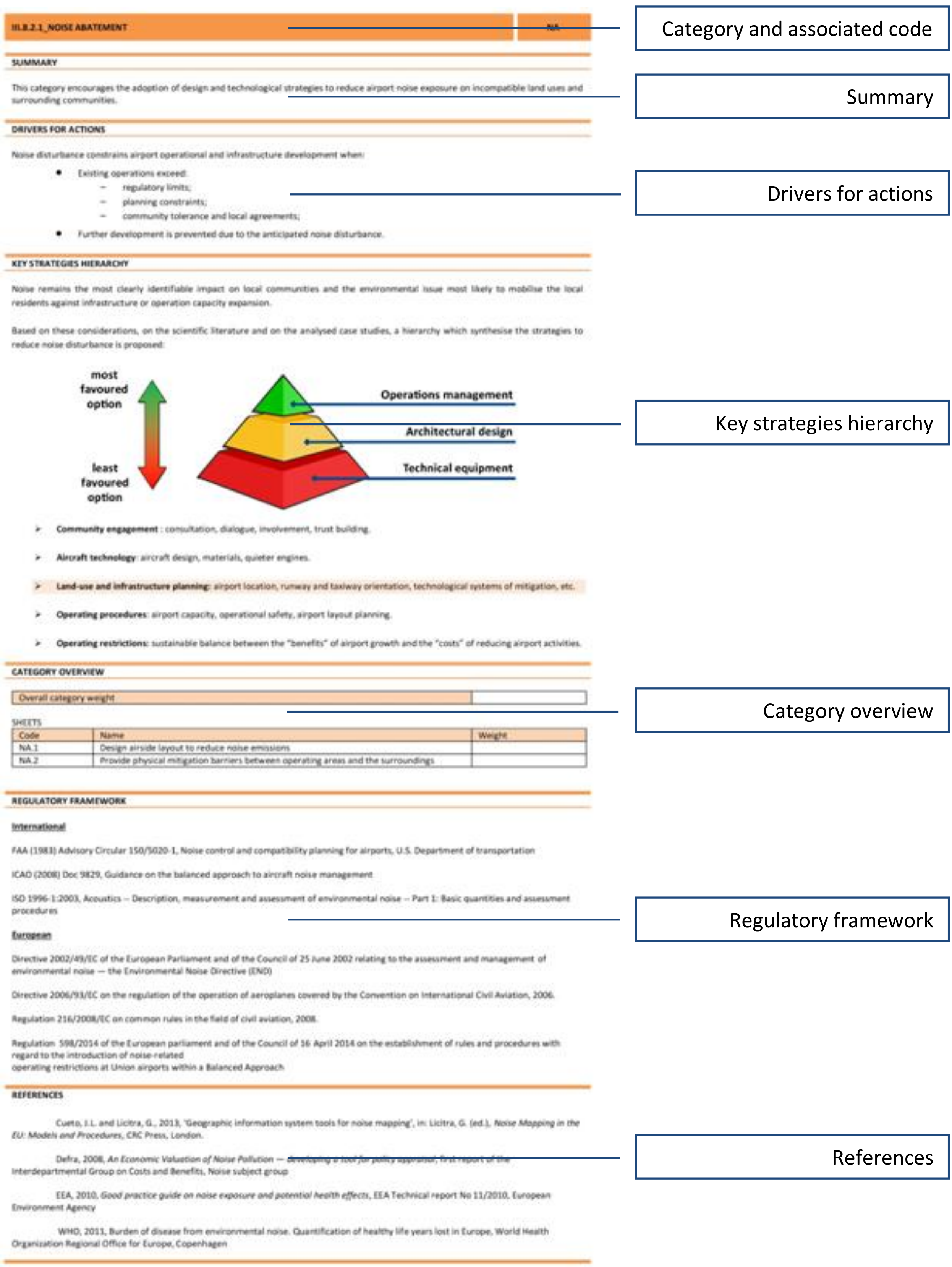
Table III.6.1_GrADE categories and requirements and associated weights

CODE	CATEGORY/REQUIREMENTS	WEIGHT	
NA	**NOISE ABATEMENT**	**19%**	
NA.1	Design airside layout to reduce noise emissions		50%
NA.2	Provide physical mitigation barriers between operating areas and the surroundings		50%
ER	**EMISSION REDUCTION AND AIR QUALITY**	**17%**	
ER.1	Design airside layout to minimise aircraft emissions		22%
ER.2	Reduce parking footprint		22%
ER.3	Develop infrastructure to increase public transport		28%
ER.4	Design infrastructure and buildings to minimise carbon and greenhouse gas emissions		28%
EN	**ENERGY USE**	**17%**	
EN.1	Design and upgrade buildings to reduce energy consumption		36%
EN.2	Design to reduce outdoor energy consumption		32%
EN.3	Use alternative and renewable energy sources		32%
WT	**WATER USE**	**6%**	
WT.1	Landscape and design to reduce water use		28%
WT.2	Design for water efficient use: employ water saving devices and/or waterless operating systems		36%
WT.3	Design to maximize water harvest, recycle and reuse		36%
WM	**WASTE MANAGEMENT & MATERIALS**	**14%**	
WM.1	Design to provide storage and collection of recyclables		26%
WM.2	Design for deconstruction, reuse and recycling		26%
WM.3	Select recycled, bio-based and rapidly renewable materials		22%
WM.4	Select materials high design service life, minimising maintenance and replacement cycles		26%
WP	**WATER POLLUTION REDUCTION**	**17%**	
WP.1	Design to reduce stormwater quantity		50%
WP.2	Design to improve stormwater quality		50%
BL	**BIODIVERSITY PRESERVATION & LAND USE**	**10%**	
BL.1	Design the layout of infrastructure to avoid destruction of sensitive habitats and protect or restore habitat and wildlife		28%
BL.2	Design infrastructure and buildings not to be attractive to some species		28%
BL.3	Landscape and design to minimise land use and reduce heat island effect		22%
BL.4	Design and technologies to reduce light pollution		22%

III.6.2_GrADE sheets: tools for the green airport design

The GrADE sheets are introduced by a summary table of the related category containing the following information (Fig. III.6.1):

- Category and code; the name of the category and the associated code identify a specific environmental issue. The use of codes associated to category and sheets is useful to ease the identification of specific references in the final report or in other documents.
- Summary; a summary of the final purpose of the category is explained in relation to the environmental issue considered and the main cause of that issue.
- Drivers for actions; the explanation of which are the main constraints to the airport operations growth and infrastructure development.
- Key strategies hierarchy; a hierarchy is proposed which sorts the main strategies (i.e. operations management, technical equipment, and architectural design) for the minimisation of the environmental issue. The hierarchy is based on scientific literature with specific regard to the best practices currently adopted and the evaluation of the answers to the survey (see Chapter 5). In particular:
    - 'Operations management' refers to all the airport-related activities for the handling and servicing passenger transport operating both landside (e.g. operations related to airport-owned vehicles) and airside (e.g. aircrafts operations on-site);
    - 'Technical equipment' refers to airport-owned vehicles, maintenance vehicles, machinery and support equipment (e.g. maintenance equipment, fire training equipment, aircrafts);
    - 'Architectural design' refers to the design of airport infrastructure which includes the master planning and design of the airport layout, the project design of terminal and other buildings, the selection of materials and components for construction.
- Category overview; the list of the requirements included in the category and the associated weights. The weights results from the analysis of the scientific literature and of the answers to the survey (see Chapters 4 and 5).
- Regulatory framework; the general regulatory references at international and European level are included to support in particular the main project design restrictions that may affect the applicability of the strategies to minimise the environmental issue considered. The framework includes regulations, standards and directives;
- References; reports from the aviation industry, papers from the academia, and specific studies from international consultants and organization are provided to support the final content of the category and related requirements.


III.8.2.1_NOISE ABATEMENT | NA

SUMMARY

This category encourages the adoption of design and technological strategies to reduce airport noise exposure on incompatible land uses and surrounding communities.

DRIVERS FOR ACTIONS

Noise disturbance constrains airport operational and infrastructure development when:

- Existing operations exceed:
  - regulatory limits;
  - planning constraints;
  - community tolerance and local agreements;
- Further development is prevented due to the anticipated noise disturbance.

KEY STRATEGIES HIERARCHY

Noise remains the most clearly identifiable impact on local communities and the environmental issue most likely to mobilise the local residents against infrastructure or operation capacity expansion.

Based on these considerations, on the scientific literature and on the analysed case studies, a hierarchy which synthesise the strategies to reduce noise disturbance is proposed:

- **Community engagement** : consultation, dialogue, involvement, trust building.
- **Aircraft technology**: aircraft design, materials, quieter engines.
- **Land-use and infrastructure planning**: airport location, runway and taxiway orientation, technological systems of mitigation, etc.
- **Operating procedures**: airport capacity, operational safety, airport layout planning.
- **Operating restrictions**: sustainable balance between the "benefits" of airport growth and the "costs" of reducing airport activities.

CATEGORY OVERVIEW

Overall category weight	

SHEETS

Code	Name	Weight
NA.1	Design airside layout to reduce noise emissions	
NA.2	Provide physical mitigation barriers between operating areas and the surroundings	

REGULATORY FRAMEWORK

International

FAA (1983) Advisory Circular 150/5020-1, Noise control and compatibility planning for airports, U.S. Department of transportation

ICAO (2008) Doc 9829, Guidance on the balanced approach to aircraft noise management

ISO 1996-1:2003, Acoustics – Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures

European

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise — the Environmental Noise Directive (END)

Directive 2006/93/EC on the regulation of the operation of aeroplanes covered by the Convention on International Civil Aviation, 2006.

Regulation 216/2008/EC on common rules in the field of civil aviation, 2008.

Regulation 598/2014 of the European parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach

REFERENCES

Cueto, J.L. and Licitra, G., 2013, 'Geographic information system tools for noise mapping', in: Licitra, G. (ed.), *Noise Mapping in the EU: Models and Procedures*, CRC Press, London.

Defra, 2008, *An Economic Valuation of Noise Pollution — developing a tool for policy appraisal, first report of the* Interdepartmental Group on Costs and Benefits, Noise subject group

EEA, 2010, *Good practice guide on noise exposure and potential health effects*, EEA Technical report No 11/2010, European Environment Agency

WHO, 2011, Burden of disease from environmental noise. Quantification of healthy life years lost in Europe, World Health Organization Regional Office for Europe, Copenhagen

Figure III.6.1_Category's summary table overview

Each category contains a different number of requirements and design specifications. A fact sheet (form) is provided for each requirement with information regarding (Fig. III.6.2):

- Application, which is divided into three categories:
    - the 'area' of the airport infrastructure influenced by the requirement (airside, terminal and other buildings, landside);
    - the specific 'design' which may affect the achievement of the final requirement (master plan, building design, technology);
    - the 'typology' of the intervention (new construction, development, refurbishment).

- Intent, that defines purpose of the requirement.

- Related requirements within the same or other categories; the arrows indicated if the related requirement affects or is affected by the requirement in the sheet.
- Performance indicator that indicates the measure to be considered for the evaluation.
- Recommended strategies that lists architectural and technological strategies for the minimisation of the environmental impacts complying with the requirement.
- Regulations, which relates to the general regulatory references (regulations, standards and directives) at international and European level.
- References which includes other rating systems and specific studies from international consultants and organisation that affected the content of the sheet.

Requirements that target a broader range of environmental 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.

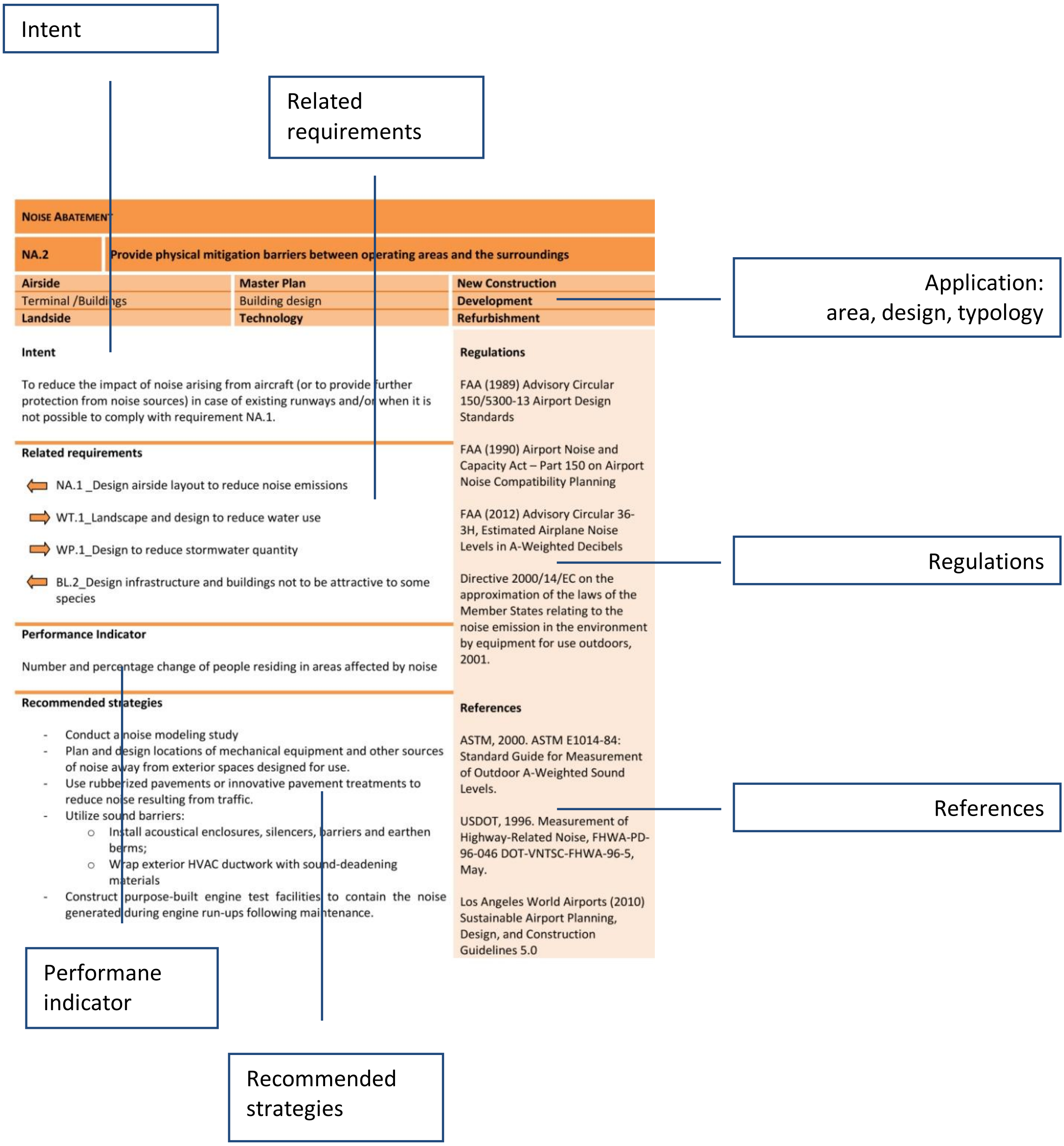


Figure III.6.2_Requirement's sheet overview

III.6.2.1_NOISE ABATEMENT | NA

SUMMARY

This category encourages the adoption of design and technological strategies to reduce airport noise exposure on incompatible land uses and surrounding communities.

DRIVERS FOR ACTIONS

Noise disturbance constrains airport operational and infrastructure development when existing operations exceed regulatory limits, planning constraints and/or community tolerance and local agreements; or when further development is prevented due to the anticipated noise disturbance.

KEY STRATEGIES HIERARCHY

Both airframe and engine designs are important in determining total aircraft noise. Aircraft and engine manufacturers have been aggressively researching low-noise technology improvements over the past 50 years and during this time there was a dramatic reduction in the noise output of all aircraft. This has been largely achieved through the improvement of aircraft design and the use of quieter engines.

The ICAO *Balanced Approach* to noise identifies three categories for land-use planning and management. These are:

- Planning Instruments: comprehensive planning, noise zoning, transfer of development rights and land and property acquisition.
- Mitigation Instruments: building regulations, sound insulation grant schemes, local property searches, physical mitigation measures.
- Financial Instruments: capital improvement, tax incentives, noise related charges that assist in funding for mitigation and community incentives.

Primarily this aims to ensure that new airport developments are located away from noise-sensitive areas and that only compatible land-use development takes place in areas affected by aircraft noise.
Airport infrastructure design and alignment can also minimize noise disturbance by directing aircraft away from built up areas (e.g. through runway positioning and orientation) or by creating a physical barrier between the operating area and surrounding housing.

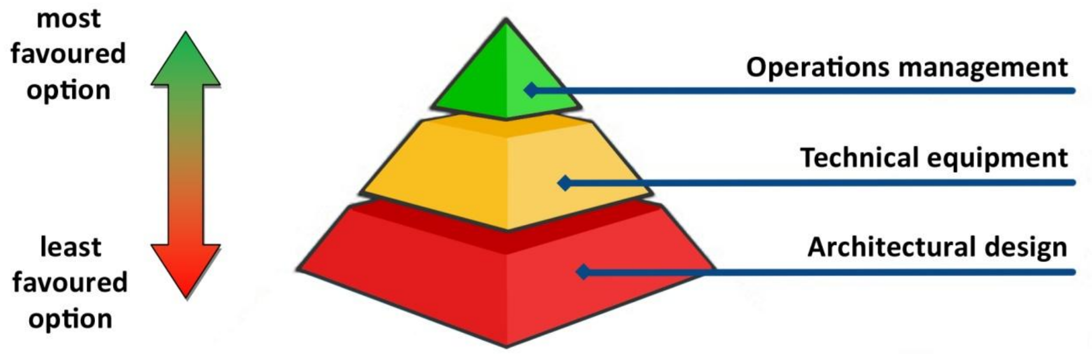
There are several possible methods for minimizing aircraft noise disturbance through revised operating procedures. The use of each technique is dependent upon the layout of the airport and surrounding areas, along with the aircraft itself.
The operational procedures are classified by ICAO into three categories:

- use of noise preferential runways to direct the flight paths of aircraft away from noise-sensitive areas;
- use of specific take-off or approach procedures to optimize the distribution of noise on the ground;
- ground handling procedures to minimize ground noise.

Operating restrictions should be a measure of last resort in managing aircraft noise. In evaluating whether operating restrictions are appropriate there is a need to balance the potential benefits to local communities against the potential losses of benefits in connectivity and employment. There are various forms of aircraft noise operating restrictions examples include:

- night flying restrictions;
- annual movement limits;
- ground movement/stand activity/engine testing restrictions.

Noise key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.19

SHEETS

Code	Name	Weight
NA.1	Design airside layout to reduce noise emissions	0.50
NA.2	Provide physical mitigation barriers between operating areas and the surroundings	0.50

REGULATORY FRAMEWORK

International

FAA (1983) Advisory Circular 150/5020-1, Noise control and compatibility planning for airports, U.S. Department of transportation

FAA (1990) Airport Noise and Capacity Act – Part 150 on Airport Noise Compatibility Planning

ICAO (2008) Doc 9829, Guidance on the balanced approach to aircraft noise management

ISO 1996-1:2003, Acoustics -- Description, measurement and assessment of environmental noise - Part 1: Basic quantities and assessment procedures

ISO 1996-2:2007, Acoustics -- Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise levels

ISO 13474:2009, Acoustics — Framework for calculating a distribution of sound exposure levels for impulsive sound events for the purposes of environmental noise assessment

ISO 20906:2009, Acoustics — Unattended monitoring of aircraft sound in the vicinity of airports

ISO 717-1:2013, Acoustics - Rating of sound insulation in buildings and of building elements -- Part 1: Airborne sound insulation

European

Directive 89/629/EEC of 4th December 1989 on the limitation of noise emission form civil subsonic jet aeroplanes, 1989.

Directive 2002/30/EC of the European Parliament and of the Council of 26 March 2002 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise — the Environmental Noise Directive (END)

Directive 2006/93/EC on the regulation of the operation of aeroplanes covered by the Convention on International Civil Aviation, 2006.

Regulation 216/2008/EC on common rules in the field of civil aviation, 2008.

Regulation 598/2014 of the European parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC, 2014.

Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2002 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' of the European Parliament and of the Council of laying down the Seventh Environment Action Programme

REFERENCES

ACI (2009) Policies and Recommended Practices Handbook, Montreal

DEFRA (2008) An Economic Valuation of Noise Pollution — developing a tool for policy appraisal, first report of the Interdepartmental Group on Costs and Benefits, Noise subject group

EEA (2010) *Good practice guide on noise exposure and potential health effects*, EEA Technical report No 11/2010, European Environment Agency

EEA (2014) Report No 10/2014, Noise in Europe 2014
European Commission (2002) *Position paper on dose response relationships between transportation noise and annoyance*, EU's Future Noise Policy, Working Group 2 (WG2) – Dose/Effect, Luxembourg

European Commission (2003) Position paper on the valuation of noise, www.ec.europa.eu/environment

JRC (2014) Common Noise Assessment Methods in Europe (CNOSSOS-EU), European Commission Joint Research Centre

WHO (2011) Burden of disease from environmental noise. Quantification of healthy life years lost in Europe, World Health Organization Regional Office for Europe, Copenhagen

NOISE ABATEMENT		
NA.1	**Design airside layout to reduce noise emissions**	
Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	Technology	Refurbishment

Intent

To reduce the impact of noise arising from aircraft operations affecting surrounding noise-sensitive buildings, through a proper configuration of runways, taxiways, and aircraft maintenance facilities to reduce exterior noise levels from aircraft noise sources.

Related requirements

⇨ NA.2_Provide physical mitigation barriers between operating areas and the surroundings

⇨ ER.1_Design airside layout to minimise aircraft emissions

⇦ WP.3_Design to protect wetlands and surface water

⇦ BL.1_Design the layout of infrastructure to avoid destruction of sensitive habitats

Performance Indicator

Number of people affected by noise

Recommended strategies

- Develop a noise exposure map and identify incompatible land use areas, and publish maps available on public website.
- Evaluate noise impacts in the planning for airside infrastructure, including runway adjustments, taxing lanes, hangars, etc.
- During airside facility planning, conduct simulation modeling of various design concepts to quantify the noise impact on the surrounding communities.

Regulations

FAA (1989) Advisory Circular 150/5300-13 Airport Design Standards

FAA (1990) Airport Noise and Capacity Act – Part 150 on Airport Noise Compatibility Planning

FAA (2012) Advisory Circular 36-3H, Estimated Airplane Noise Levels in A-Weighted Decibels

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise — the Environmental Noise Directive (END)

Standards

ISO 1996-1:2003, Acoustics - Description, measurement and assessment of environmental noise - Part 1: Basic quantities and assessment procedures

ISO 1996-2:2007, Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise levels

ISO 717-1:2013, Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne

- In the planning stages, design runway and taxiway layouts in a manner that will result in the most efficient movement of aircraft and the reduction of taxi/idle time;

- In the planning stages, design the locations and layouts of new terminals and gates in a manner that minimizes taxi distances;
- A stated objective of new or modified airside facilities shall be to maximize the efficient layout of airside facilities with the express purpose of minimizing taxi distances and taxi times

sound insulation

References

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

NOISE ABATEMENT

NA.2	Provide physical mitigation barriers between operating areas and the surroundings

Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	**Technology**	Refurbishment

Intent

To reduce the impact of noise arising from aircraft (or to provide further protection from noise sources) in case of existing runways and/or when it is not possible to comply with requirement NA.1.

Related requirements

⇦ NA.1 _Design airside layout to reduce noise emissions

⇨ WT.1_Landscape and design to reduce water use

⇨ WP.1_Design to reduce stormwater quantity

⇦ BL.2_Design infrastructure and buildings not to be attractive to some species

Performance Indicator

Number and percentage change of people residing in areas affected by noise

Recommended strategies

- Conduct a noise modeling study
- Plan and design locations of mechanical equipment and other sources of noise away from exterior spaces designed for use
- Use rubberized pavements or innovative pavement treatments to reduce noise resulting from traffic
- Utilise sound barriers:
    - Install acoustical enclosures, silencers, barriers and earthen berms;
    - Wrap exterior HVAC ductwork with sound-

Regulations

FAA (1989) Advisory Circular 150/5300-13 Airport Design Standards

FAA (1990) Airport Noise and Capacity Act – Part 150 on Airport Noise Compatibility Planning

FAA (2012) Advisory Circular 36-3H, Estimated Airplane Noise Levels in A-Weighted Decibels

Directive 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors, 2001.

Standards

ISO 9613-2:1996
Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation

References

ASTM, 2000. ASTM E1014-84: Standard Guide for Measurement of Outdoor A-Weighted Sound Levels.

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport

deadening materials - Construct purpose-built engine test facilities to contain the noise generated during engine run-ups following maintenance.	Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

III.6.2.2_EMISSION REDUCTION AND AIR QUALITY | ER

SUMMARY

This category encourages the adoption of design and technological strategies to reduce overall airport emissions from day-to-day operations and streamline compliance with air quality regulations and requirements.

DRIVERS FOR ACTIONS/CONSTRAINTS

Constraints to airport operational and infrastructure development rise when gaseous emissions exceed the emissions standards or air quality limits established by the legislative requirements and regulatory controls for protection of health and environment.
After noise, local air quality is one of the other main environmental issues that gives rise to airport constraints, either through regulatory restrictions or community concerns about odours and health fears. Air quality legislation has the potential to constrain airport growth either by restricting aircraft movements or road traffic.

KEY STRATEGIES HIERARCHY

In the last 40 years, airframe design and engine technology improvements have produced aircraft which today are about 70% more fuel efficient per passenger-km. New airframe technologies may be viable in the long term, but would require new aircraft designs and new infrastructure for supply. It is forecasted that the development of new aircraft technologies will take 10-20 years to emerge and will take many years to replace the existing airline fleet and possibly to adapt the current airport infrastructure to the new aircraft models.

Infrastructural strategies for minimizing carbon emissions are divided in four categories:

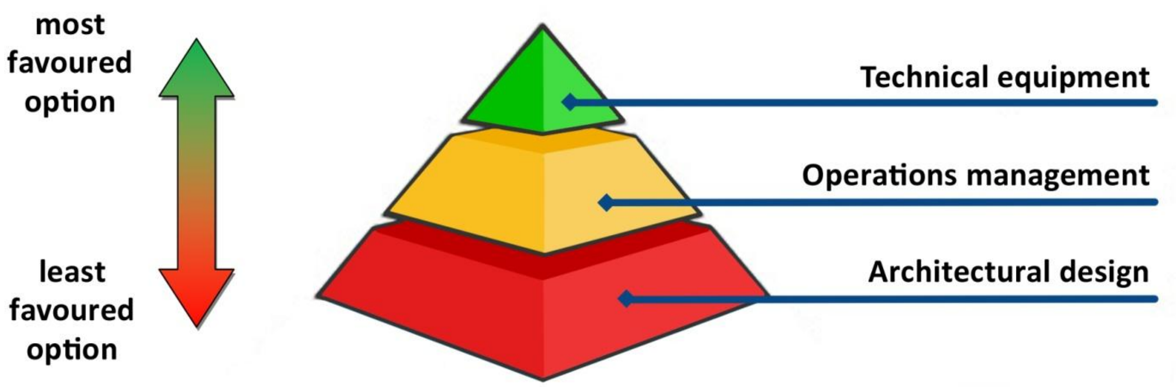
- Ground transport system
  - Airports can develop themselves as inter-modal transport hubs by including local and region bus and coach facilities, and train stations for local trains, light rail, subway/metro systems, and regional/international trains.

- Renewable energy
  - Programmes to improve building energy efficiency can provide meaningful cost savings, while at the same time contributing to reductions in emissions.

- Airport design and resources management
  - New buildings should employ best practice energy efficiency technology; existing building should be reviewed for energy efficiency and retrofits conducted where appropriate
  - New and existing buildings should have best practical thermal insulation and glazing
  - The design of the whole airport infrastructure should consider:
    - Improvements in aircraft taxiways, terminal and runway configuration to

reducing taxiing distance and ground and terminal area congestion;
- Solid waste management that includes recycling and composting, and reduces volumes of waste going to landfills. Reusing excavation and demolition material on-site also reduces transportation emissions.

Emissions key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.17

SHEETS

Code	Name	Weight
ER.1	Design airside layout to minimise aircraft emissions	0.22
ER.2	Reduce parking footprint	0.22
ER.3	Develop infrastructure to increase public transport	0.28
ER.4	Design infrastructure and buildings to minimise carbon and greenhouse gas emissions	0.28

REGULATORY FRAMEWORK

International

International Civil Aviation Organization (2011) Doc 9889. *Airport Air Quality Manual*

ISO 14064-1:2006, Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

ISO 14064-2:2006, Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal

enhancements

ISO 11771:2010, Air quality — Determination of time-averaged mass emissions and emission factors — General approach

ISO 16745: 2015, Environmental performance buildings – Carbon metric of a building

European

Commission Decision 2004/224/EC laying down the obligation of Member States to submit within two years so-called *Plans and Programmes* for those air quality zones where certain assessment thresholds set in the Directives are exceeded

Directive 1996/62/EC on ambient air quality assessment and management *(Air Quality Framework Directive)*

Directive 2000/69/EC of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air

Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air

Directive 2003/87/EC, It established the European Emissions Trading Scheme (ETS) providing for companies in certain sectors the limitation of GHG emissions under an established cap.

Directive 2004/107/EC of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air

Directive 2008/101/EC, It reviews the Directive 2003/87/EC including aviation activities into EU ETS
It established the criteria for monitoring and reporting emissions from aviation activities, as well as criteria for the verification of emissions from the same activities.

Directive 2008/50/EC on ambient air quality and cleaner air for Europe

Directive 2009/29/EC, It amended the Directive 2003/87/EC, introduced more stringent emission limits and stipulated that EU-wide quantities of emissions.

REFERENCES

Airport Council International (2009) *Airport Carbon Accreditation scheme* (www.aci.org/aca)

Airport Council International (2009) *Guidance Manual: Airport Greenhouse Gas Emissions Management*

IATA – International Air Transport Association (2013) Technology Roadmap, in collaboration with the German Aerospace Center (DLR) and the Georgia Institute of Technology, 4th Edition

IATA – International Air Transport Association (2013) Responsibly Addressing Climate Change

World Resource Institute (2004) *The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard*

EMISSION REDUCTION AND AIR QUALITY

ER.1	Design airside layout to minimise aircraft emissions

Airside	**Master Plan**	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	Technology	Refurbishment

Intent

To mandate that new or modified airside facilities be planned with the purpose of reducing taxi distances, taxi times, and aircraft delay to the maximum extent practicable to reduce emissions of greenhouse gases and criteria and hazardous air pollutants. This requirement extends to the planning and design or redesign of runways, taxiways and terminals.

Related requirements

- NA.1_Design airside layout to reduce noise emissions
- WP.3_Design to protect wetlands and surface water
- BL.1_Design the layout of infrastructure to avoid destruction of sensitive habitats

Performance Indicator

Percentage reduction of carbon emissions (during aircrafts operations on-site)

Recommended strategies

- Measures that reduce taxiing and queuing, such as the construction of efficient and direct taxiways, virtual queuing, holding aircraft at terminal gates and runway capacity enhancements, will contribute to reduced fuel burn and lower emissions
- Design runway and taxiway systems such that aircraft are not required to cross a runway after landing, to the extent practicable.
- Design parallel runways with sufficient separation to preclude the need for aircraft to hold for other aircraft,

Regulations

FAA (1989) Advisory Circular 150/5300-13 Airport Design Standards

Directive 1996/62/EC on ambient air quality assessment and management *(Air Quality Framework Directive)*

Directive 2008/101/EC, it reviews the Directive 2003/87/EC including aviation activities into EU ETS

Standards

ISO 14064-2:2006, Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements

ISO 11771:2010, Air quality — Determination of time-averaged mass emissions and emission factors — General approach

References

Sustainable Airport Planning, Design and Construction Guidelines, Los Angeles World Airports (LAWA)

to the extent practicable. - Design runway systems with high-speed exits, end-around taxiways, centerline taxiways or other facilities to maximize the efficient flow of aircraft. - Provide doublewide taxiways to facilitate the movement of aircraft, where practicable. - Ensure that the airfield layout provides room for an aircraft to hold without delaying other aircraft. - Provide sufficient ramp area to reduce ramp congestion, where practicable.	

EMISSION REDUCTION AND AIR QUALITY

ER.2	Reduce parking footprint

Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	Technology	Refurbishment

Intent

To encourage the use of alternative means of transport other than the private car to and from the building, thereby helping to reduce transport-related emissions and traffic congestion associated with the building's operation.

Related requirements

⇐ ER.3_Develop infrastructure to increase public transport

⇒ WP.1_Design to reduce stormwater quantity

⇒ WP.2_Design to improve stormwater quality

⇒ BL.3_Landscape and design to minimise land use and reduce heat island effect

Performance Indicator

Car parking capacity

Recommended strategies

- Use traffic flow monitoring and modeling for planning at the beginning of the planning and design process

- Plan for the development of preferred parking and/or lot locations for alternative fuel rental vehicles, carpools and vanpools. Provide preferred parking for vanpools and carpools for staff. Preferred Parking refers to the parking spots that are closest to the main entrance of the project, exclusive of spaces designated for handicapped, or spaces designated for specific users

- Consider sharing parking facilities with adjacent buildings
- Consider alternatives that will limit the use of single

Regulations

FAA (1989) Advisory Circular 150/5300-13 Airport Design Standards

Directive 2008/101/EC, it reviews the Directive 2003/87/EC including aviation activities into EU ETS

Standards

ISO 21542:2011, Building construction – Accessibility and usability of the built environment

ISO 14813:2011, Intelligent Transport System – Reference model architecture for the ITS sector

References

Building Research Establishment Environmental Assessment Methodology (BREEAM)

Klementschitz, R., Stark, J., and G. Sammer, (2007), Integrating mobility management in land development planning with off-street parking regulations, Journal of Urban Planning and Development, 133:2, 107-113

Leadership in Energy and Environmental Design (LEED)

occupancy vehicles - Provide a waiting area for vehicles that are conducting passenger pick-up. Provide remote check-in facilities - Use an off-site delivery consolidation center to reduce delivery traffic and enact minimum delivery volume restrictions to minimize number of daily deliveries on airport infrastructure	Sustainable Airport Manual, Chicago Department of Aviation (CDA) Sustainable Airport Planning, Design and Construction Guidelines, Los Angeles World Airports (LAWA)

EMISSION REDUCTION AND AIR QUALITY	
ER.3	**Develop infrastructure to increase public transport**

Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	Technology	Refurbishment

Intent

To recognise and encourage development in proximity of good public transport networks, thereby helping to reduce transport-related pollution and congestion.

Related requirements

- ER.2_Reduce parking footprint
- BL.1_Design the layout of infrastructure to avoid destruction of sensitive habitats

Performance Indicator

Percentage reduction of carbon emissions from public transport modes

Recommended strategies

- Perform a transportation survey of future building occupants to identify transportation needs and share results to encourage knowledge and use of mass transit. Whenever possible, co-locate buildings and mass transit and provide clear directional signage.
- Perform a transportation survey of future building occupants to identify transportation needs and share results to encourage knowledge and use of mass transit. Whenever possible, co-locate buildings and mass transit and provide clear directional signage.
- Use a 10-year project projection for public transportation plans. Plan and design walking paths from the public transit stops.
- Improve and/or increase public transportation access from the City and suburbs
- Construct airport to airport high-speed rail connection

Regulations

European Commission (2013) Communication from the Commission 'Together towards competitive and resource-efficient urban mobility'

Standards

ISO 37120:2014, Sustainable development communities – Indicators for city services and quality of life

References

Airport Council international, Airport Carbon Accreditation Scheme, http://www.airportcarbonaccredited.org/

Building Research Establishment Environmental Assessment Methodology (BREEAM)

Leadership in Energy and Environmental Design (LEED)

Transportation Research Board (2010) Urban mobility plans throughout europe: a definitive challenge towards sustainability

Sustainable Airport Manual, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design

- Develop Airport-Downtown express connection, including satellite check-in facilities - Develop additional train/mass transit service to/from the suburbs	and Construction Guidelines, Los Angeles World Airports (LAWA) Prototype Airport Sustainability Rating System - Characteristics, Viability, and Implementation options, Airport Cooperative Research Program (ACRP)

EMISSION REDUCTION AND AIR QUALITY

ER.4	Design infrastructure and buildings to minimise carbon and greenhouse gas emissions

Airside	Master Plan	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

To encourage the adoption of design measures, which reduce carbon emissions and minimise reliance on active building services systems.

Related requirements

⇐ EN.1_Design and upgrade buildings to reduce energy consumption

⇐ WM.2_Design for deconstruction, reuse and recycling

⇐ WM.4_Select materials with high service life, minimising maintenance and replacement cycles

Performance Indicator

Percent reduction of greenhouse gas emission intensity per gross square foot from a baseline.

Recommended strategies

- Develop sustainable design guidelines for upgrades or new construction of terminal and administrative buildings
- Prepare an airport-wide GHG emissions inventory that is publicly available
- Assess feasibility of including GHG reduction measures in the project design, specifically energy consumption reduction, reuse, or alternatives such as solar energy generation
- Design and operate the facility without mechanical cooling and refrigeration equipment. Where mechanical cooling is used, utilize base building HVAC and refrigeration systems for the refrigeration cycle that minimize direct impact on ozone depletion and global warming.

Standards

ISO 14064-1:2006, Greenhouse Gases – Part 1: Specification with guidance at the organisational level for quantification and reporting of greenhouse gas emissions and removals

ISO 14064-3: 2006, Greenhouse Gases – Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions"

References

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment Method (BREEAM)

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

III.6.2.3_ENERGY USE | EN

SUMMARY

This category encourages the adoption of design and technological strategies to use energy efficiently and reduce its consumption.

DRIVERS FOR ACTIONS/CONSTRAINTS

The increasing demand for resources in constrained by the decline of supply availability and the increasing costs. These factors are even more critical if we consider their impact on the surrounding areas and the city (e.g. increasing competition for grid supplies). This complex scenario places significant economic and political pressure on airport managers to accurately assess their airport's performance and minimise the airport's environmental footprint regarding the use of resources.
Drivers for action are therefore: to meet customer demand, to maintain levels of service, to maintain infrastructure, whilst reducing costs and quantities used.

KEY STRATEGIES HIERARCHY

The most sustainable approach to resource management is for airports to seek to become self-sufficient in energy by maximising opportunities for minimising consumption, using efficiently, harvesting, reusing water and employing low emissions source of energy.

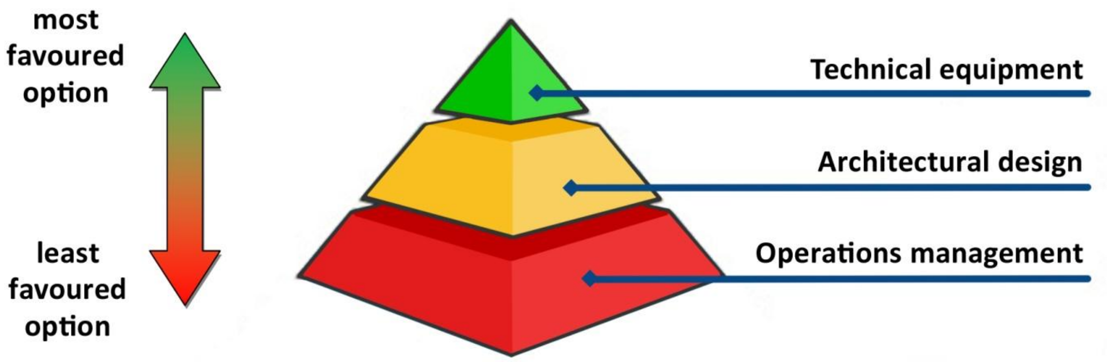
Energy supplies will be secured through the incorporation of renewable energy generation into airport infrastructure. Infrastructure design, technologies and management systems employed will ensure minimum use of energy across the site. These same actions will minimise carbon emissions. Some airports have invested in their own power-generation systems.

- Use of non-renewable and polluting energy sources should be reduced while sustainable energy sources should increasingly supply airport energy needs.

- Designing and constructing a new building provides many opportunities to implement energy efficiency technologies. "Green designs", "smart" building management systems and the like are much more easily incorporated at the planning and design stages, but many can be installed as a retrofit to an existing building.

- Heating, Ventilation and Air Conditioning (HVAC) is one of the major energy consumers at most airports. Efficiency improvement projects can have short payback periods and provide both climate change and local air quality benefits. Many traditional and innovative technologies are available, some for new installations and some as retrofits:

Energy key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.17

SHEETS

Code	Name	Weight
EN.1	Design and upgrade buildings to reduce energy consumption	0.36
EN.2	Design to reduce outdoor energy consumption	0.32
EN.3	Use alternative and renewable energy sources	0.32

REGULATORY FRAMEWORK

International

FAA (2012) Advisory Circular 150/5345-53D – Airport Lighting Equipment Certification program

FAA (2014) Advisory Circular 150/5340-30H – Design and installation details for airport visual aids

ISO 8995-1: 2002, Lighting of work places – Part 1: Indoor

ISO 8995-3: 2006, Lighting of work places – Part 3: Lighting requirements for safety and security of outdoor work places

ISO 13790: 2008, Energy performance of buildings – Calculation of energy use for space heating and cooling

ISO 50001:2011, Energy management systems – Requirements with guidance for use

ISO 14825: 2011, Intelligent transport systems

ISO 25745-1: 2012, Energy performance of lifts, escalators and moving walks – Part 1: Energy measurement and verification

ISO 5149-1: 2014, Refrigerating systems and heat pumps – Safety and environmental requirements – Part 1: Definitions, classification and selection criteria

ISO 5149-2: 2014, Refrigerating systems and heat pumps – Safety and environmental requirements – Part 2: Design, construction, testing, marking and documentation

ISO 50004: 2014, Energy management systems – Guidance for the implementation. Maintenance and improvement of an energy management system

ISO/IEC 13273-1: 2015, Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency

ISO/IEC 13273-1: 2015, Energy efficiency and renewable energy sources – Common international terminology – Part 2: Renewable energy sources

European

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

Directive 2010/31/EC of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency

REFERENCES

Enhanced Capital Allowance (ECA) Scheme Energy Technology Product List (ETPL): https://etl.decc.gov.uk/etl/site.html

Energy Star labelling scheme, www.energystar.gov

European Commission (2010) Energy 2020 - A strategy for competitive, sustainable, secure energy, COM(2010) 639 final

European Commission (2014) Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy, COM(2014) 520 final

ENERGY USE

EN.1	**Design and upgrade buildings to reduce energy consumption**	
Airside	Master Plan	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

To reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the building and its systems. To recognise and encourage buildings designed to minimise operational energy demand, primary energy consumption.

Related requirements

ER.4_Design infrastructure and buildings to minimise carbon and GHG emissions

WM.1_Design to provide storage and collection of recyclables

Performance Indicator

Percent reduction of airport buildings energy use intensity from a baseline

Recommended strategies

- Identify the factors of thermal comfort and a process for developing comfort criteria for building spaces that suit the needs of the occupants involved in their daily activities.
- Design the building and systems with comfort controls to allow adjustments to suit individual needs or those of groups in shared spaces.

- Employ heat recovery from equipment rooms, such as an in-line baggage room, and apply to other areas of the site.
- Utilise thermal storage to decrease peak loading.

- Orient building to optimize passive solar and/or daylight penetration
- Optimize architectural features for daylighting and glare control

Regulations

Directive 2010/31/EC of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency

Standards

ISO 8995-1: 2002, Lighting of work places – Part 1: Indoor

ISO 13790: 2008, Energy performance of buildings – Calculation of energy use for space heating and cooling

ISO 5149-1: 2014, Refrigerating systems and heat pumps – Safety and environmental requirements – Part 1: Definitions, classification and selection criteria

ISO 5149-2: 2014, Refrigerating systems and heat pumps – Safety and environmental requirements – Part 2: Design, construction, testing, marking and documentation

References

Enhanced Capital Allowance (ECA) Scheme Energy Technology Product

- Design the building envelope and systems and any powered civil infrastructure systems to meet baseline requirements. - Evaluate appropriate levels of insulation and for building envelope - Organise circuiting of lighting and building systems so that individual areas may be separately controlled relative to daylight and heating/cooling zones - Consider light shelves, ceiling design, window placement, and window treatments; Use high performance glazing (double glazed, low-e) and window systems - Provide energy efficient lighting systems including LED, fluorescent lighting, solar lighting and the use of lighting sensors or timers	List (ETPL): https://etl.decc.gov.uk/etl/site.html Sustainable Airport Manual, version 3.2, 2014, Chicago Department of Aviation (CDA) Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA) Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

ENERGY USE		
EN.2	**Design to reduce outdoor energy consumption**	
Airside	Master Plan	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Overall airport energy use advances optimal energy performance across all airport operations to reduce operating expenses and minimize resource consumption without impacting airport critical functions.

Related requirements

⇨ ER.4_design infrastructure and buildings to minimise carbon and ghg emissions

⇨ WP.2_Design to improve stormwater quality

⇨ BL.4_Design and technologies to reduce light pollution

Performance Indicator

Percent reduction of total airport energy use intensity from a baseline

Recommended strategies

- Include requirement for preconditioned air units in bid documents for gate design and renovation projects.
- Establish and follow systems commission requirements for runway lighting and illuminated signage, runway site lighting systems, traffic signals, pump stations, and oil/water separators.
- Convert conventional airfield lighting to LED
- Install variable speed fans for HVAC systems
- Establish lease provisions that require preconditioned air units at gates with 400 Hz power, for new terminal leases.

Regulations

FAA (2012) Advisory Circular 150/5345-53D – Airport Lighting Equipment Certification program

FAA (2014) Advisory Circular 150/5340-30H – Design and installation details for airport visual aids

Standards

ISO 8995-3: 2006, Lighting of work places – Part 3: Lighting requirements for safety and security of outdoor work places

ISO 14825: 2011, Intelligent transport systems

ISO 25745-1: 2012, Energy performance of lifts, escalators and moving walks – Part 1: Energy measurement and verification

References

Energy Star labelling scheme, www.energystar.gov

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

ENERGY USE			
EN.3	**Use alternative and renewable energy sources**		
Airside	**Master Plan**	**New Construction**	
Terminal /Buildings	Building design	**Development**	
Landside	**Technology**	**Refurbishment**	

Intent

Encourage and recognise increasing levels of on-site renewable energy self-supply and use of grid-source, renewable energy technologies on a net zero pollution basis in order to reduce environmental and economic impacts associated with fossil fuel energy use.

Related requirements

⇨ ER.4_Design infrastructure and buildings to minimise carbon and ghg emissions

⇦ EN.1_Design and upgrade buildings to reduce energy consumption

⇦ EN.2_Design to reduce outdoor energy consumption

⇨ WM.1_Design to provide storage and collection of recyclables

⇦ BL.1_Design the layout of infrastructure to avoid destruction of sensitive habitats

Performance Indicator

Percentage of renewable energy use on the total energy consumption

Recommended strategies

- Conduct a life-cycle assessment of the alternative or renewable energy system to ensure a cumulative positive impact on the environment, economy and community
- Develop and install on-site energy generation devices utilizing alternative or renewable energy sources.
- Renewable resources include wind, solar, tidal, geothermal

Regulations

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

Standards

ISO/IEC 13273-1: 2015, Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency

ISO/IEC 13273-1: 2015, Energy efficiency and renewable energy sources – Common international terminology – Part 2: Renewable energy sources

References

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment Method (BREEAM)

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual,

low-impact hydro, biomass and bio-gas strategies, and newly developed techniques or energy systems that are not based on petroleum fuels and are carbon neutral during operation. - Assess the project for non-polluting and renewable energy potential including solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, take advantage of net metering with the local utility. - Electricity generation using bio-fuels (untreated wood waste, agricultural crops or waste, landfill gas) - Alternative resources may include cogeneration systems, biogas, biodiesel and advanced coal-based fuels or tar sands that reduce carbon emissions through carbon sequestration or other methods that can mitigate the carbon sources. Hydrogen- based fuels can also be refined from coal-based fuels and used provided the carbon has been sequestered or contained from the atmosphere.	version 3.2, 2014, Chicago Department of Aviation (CDA) Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA) Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

III.6.2.4_WATER USE | WT

SUMMARY

This category encourages the adoption of design and technological strategies to use water resources efficiently and reduce its consumption.

DRIVERS FOR ACTIONS/CONSTRAINTS

The increasing demand for resources in constrained by the decline of supply availability and the increasing costs. These factors are even more critical if we consider their impact on the surrounding areas and the city (e.g. increasing competition for grid supplies). This complex scenario places significant economic and political pressure on airport managers to accurately assess their airport's performance and minimise the airport's environmental footprint regarding the use of resources.
Drivers for action are therefore: to meet customer demand, to maintain levels of service, to maintain infrastructure, whilst reducing costs and quantities used.

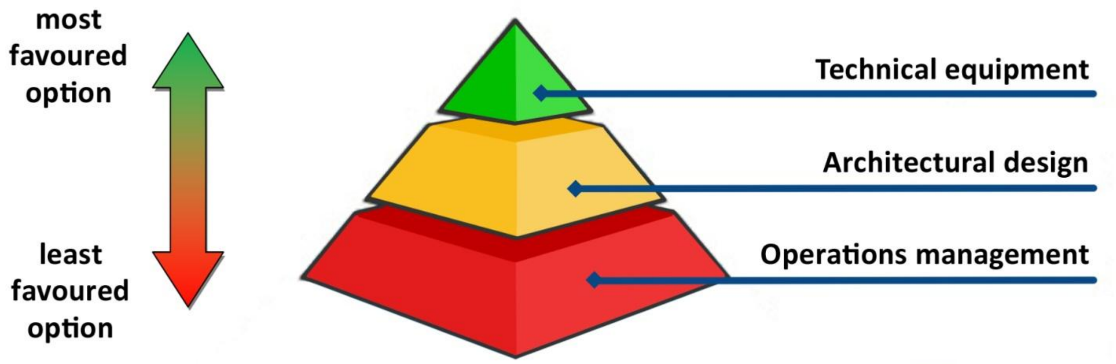
KEY STRATEGIES HIERARCHY

The most sustainable approach to resource management is for airports to seek to become self-sufficient in water supply by maximising opportunities for minimising consumption, using efficiently, harvesting, reusing water and employing low emissions source of energy.

Water use will be minimised through the adoption of waterless operating systems (e.g. cleaning, urinals), the introduction of a dual water system across the site, through water reuse, recycling and purification systems as well as technologies and operational systems to minimise wastes in water use. Other sources of water comes from desalination plants and collecting and storing rainfall.
Sources of water include municipal supply, underground aquifers, surface water (including artificial dams) and rain water (from building roofs). Some airports have their own wastewater processing plants. Good water management practices include the following:

- Installation of water saving devices such as waterless urinals, infrared toilet flush controls, self-closing sink taps and low flow shower heads.
- Rain water collection and grey-water recycling for non-potable uses such as toilet flushes and landscape (garden watering).
- Computer-controlled, "smart" irrigation systems
- Water-efficient central heating and cooling systems
- Water recycling of vehicle wash and other lightly contaminated effluents.
- Prevention of incidental loss through leakage.

Water key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.06

SHEETS

Code	Name	Weight
WT.1	Landscape and design to reduce water use	0.28
WT.2	Design for water efficient use	0.36
WT.3	Design to maximize water harvest, recycle and reuse	0.36

REGULATORY FRAMEWORK

International

FAA (2008) Management of airport industrial waste

ISO 24511: 2007, Activities relating to drinking water and wastewater services – Guidelines for the management of wastewater utilities and for the assessment of wastewater services

ISO 16075-1: 2015, Guidelines for treated wastewater use for irrigation projects – Part 1: the basis of a reuse project for irrigation

European

Directive 200/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, EU Water Directive

REFERENCES

EEA (2012) Towards efficient use of water resources in Europe, Copenhagen

European Commission (2007) Addressing the challenge of water scarcity and droughts in the European Union, COM(2007) 414 final

European Commission (2015) Optimising water reuse in the EU, Luxemburg

European Commission (2015) The water framework directive and the floods directive: actions towards the 'good status' of EU water and to reduce flood risks

FAA (2013) Recycling, reuse and waste reduction at airports, a synthesis document, Washington

Global Water Partnership, EU Water Initiative, http://www.gwp.org

IPCC (2008) Climate change and water, technical paper IV, Geneva

USEPA, WaterSense Program, www.epa.gov/watersense

WHO (2010) Water for health. World Health Organisation Guidelines for drinking-water quality

WATER USE

WT.1	**Landscape and design to reduce water use**

Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	Technology	Refurbishment

Intent

Limit or eliminate the use of potable water, or other natural surface or subsurface water resources available on or near the project site, for landscape irrigation.

Related requirements

- ⇨ EN.2_Design to reduce outdoor energy consumption
- ⇨ WT.3_Design to maximise water harvest, recycle, and reuse
- ⇨ WP.1_Design to reduce stormwater quantity
- ⇦ WP.3_Design to protect wetlands and surface water
- ⇦ BL.2_Design infrastructure and buildings not to be attractive to some animal species

Performance Indicator

Percentage of reduction water use for landscaping from a baseline

Recommended strategies

- Perform a soil/climate analysis to determine appropriate plant material and design the landscape with native or adapted plants to reduce or eliminate irrigation requirements. Where irrigation is required, use high-efficiency equipment and/or climate-based controllers.
- Utilise vegetation which may be acceptable for site use (native and/or low- maintenance), with special consideration for vegetated green roofs. Utilize vegetation to reduce or eliminate irrigation requirements for landside areas.
- Consider drought resistant vegetation that does not attract wildlife

Standards

ISO 16075-1: 2015, Guidelines for treated wastewater use for irrigation projects – Part 1: the basis of a reuse project for irrigation

References

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, version 3.2, 2014, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

- If irrigation system must be installed, provide for soil moisture monitoring to reduce reliance on manual control and timed devices, as well as for detecting leaks
- Employ high-efficiency irrigation systems with a slow-drip, sub-soil irrigation and automated linkages to meteorological data.
- Evaluate stormwater and/or graywater cisterns for capturing rainwater from all new roofs for irrigation

WATER USE

WT.2	Design for water efficient use	
Airside	Master Plan	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	**Technology**	**Refurbishment**

Intent

To reduce the consumption of potable water for sanitary use in new buildings from all sources through the use of water efficient components and water recycling systems.

Related requirements

➡ ER.4_Design infrastructure and buildings to minimise carbon and ghg emissions

➡ EN.1_Design and upgrade buildings to reduce energy consumption

⬅ WP.2_Design to improve stormwater quality

Performance Indicator

Percent reduction of potable water use intensity from a baseline

Recommended strategies

- Special consideration should be used to distinguish applicability of these technologies in high-volume passenger terminal areas versus office facilities, especially with respect to maintenance.
- Special consideration should be used to distinguish applicability of these technologies in high- volume passenger terminal areas versus office facilities, especially with respect to maintenance.

- Use high- efficiency fixtures (water closets and urinals) and dry fixtures such as composting toilet systems to reduce the potable water demand.
- Install dry fixtures such as composting toilets and waterless urinals to reduce wastewater volumes

Standards

ISO 24511: 2007, Activities relating to drinking water and wastewater services – Guidelines for the management of wastewater utilities and for the assessment of wastewater services

References

EEA (2012) Towards efficient use of water resources in Europe, Copenhagen

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment Method (BREEAM)

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

USEPA, WaterSense Program, www.epa.gov/watersense

- Use instantaneous hot water heating systems (i.e., tankless, on-demand hot water heating) - Establish a water supply system that supports vehicle maintenance without the use of potable water by using recycled water or diverted stormwater for vehicle and aircraft washing - A leak detection system which is capable of detecting a major water leak on the mains water supply within the building and between the building and the utilities water meter is installed. - Flow control devices that regulate the supply of water to each WC area/facility according to demand are installed (and therefore minimise water leaks and wastage from sanitary fittings).	

WATER USE		
WT.3	**Design to maximize water harvest, recycle and reuse**	
Airside	**Master Plan**	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Reclaim and reuse wastewater and storm water to reduce potable water demand and preserve natural water resources. Reduce wastewater generation and potable water demand while increasing the local aquifer recharge.

Related requirements

⇨ EN.2_Design to reduce outdoor energy consumption

⇦ WT.1_Landscape and design to reduce water use

⇦ WT.2_Design for water efficient use

⇨ WP.1_Design to reduce stormwater quantity

⇦ WP.2_Design to improve stormwater quality

⇨ WP.3_Design to protect wetlands and surface water

Performance Indicator

Percentage of reused water on the total water consumption

Recommended strategies

- Consider reusing stormwater or graywater for sewage conveyance or on-site mechanical and/or natural wastewater treatment systems. Options for on-site wastewater treatment include packaged biological nutrient removal systems and high-efficiency filtration systems.
- Capture graywater from lavatories, showers and institutional dishwashing facilities for sewage conveyance or on-site wastewater treatment systems
- Use reclaimed greywater and/or harvested stormwater for

Regulations

FAA (2008) Management of airport industrial waste

Standards

ISO 24511: 2007, Activities relating to drinking water and wastewater services – Guidelines for the management of wastewater utilities and for the assessment of wastewater services

References

FAA (2013) Recycling, reuse and waste reduction at airports, a synthesis document, Washington

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, version 3.2, 2014, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

non- potable needs like building sewage conveyance, cooling tower make-up, vehicle maintenance and landscape irrigation. - Design plumbing to use reclaimed water from reclaimed water pipeline from a nearby wastewater treatment facility - Develop stormwater collection/rain-harvesting system for reuse.	

III.6.2.5_WASTE MANAGEMENT & MATERIALS | WM

SUMMARY

This category encourages the adoption of design and technological strategies for the efficient use of materials and the reduction of environmental contamination from waste discharges.

DRIVERS FOR ACTIONS/CONSTRAINTS

Sustainable development acknowledges the fact that the earth's resources are limited and that their extraction, consumption, and disposal have significant environmental impacts.
Drivers for waste management include international and national regulatory requirements, the increasing cost of waste treatment and disposal, the practicalities of handling large quantities of waste, and an acknowledgment of corporate responsibility. Although waste management regulations differ between countries and even between states, they do have common features relating to:

- The handling of "special" wastes that are harmful to humans or the environment or have been transported across national borders, including chemicals, clinical and radioactive wastes, and foodstuffs;
- Prioritising waste minimisation in order to reduce the generation of waste in the first place, before other management options are considered;
- The need to promote the reuse and recycling of materials and dissuade the dumping of waste in landfills;
- The opportunities of waste to energy generation through incineration.

KEY STRATEGIES HIERARCHY

Sustainable waste management seeks to minimise the amount of waste generated in the first instance but then acknowledges that waste materials, if properly segregated, are valuable resources that can deliver significant financial returns as well as environmental benefits. A key to reducing waste at the source is minimisation at the point of purchase through the supply chain. This can however, have infrastructure implications, if for example the airport operator chooses to bulk buy products to reduce packaging and handling costs.

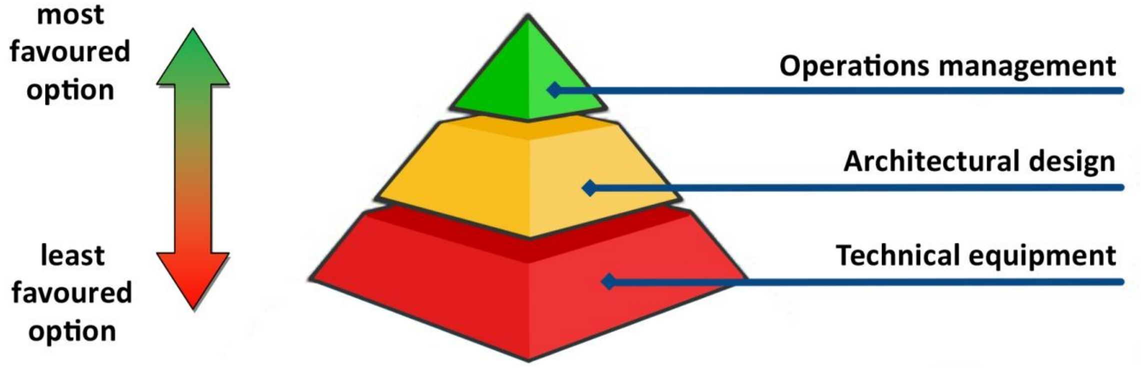
The separation of wastes on site allows the airport operator to reuse or sell materials to external contractors, or use them for composting or energy generation in contrast to having to pay external companies to collect and then process the untreated waste.

Airport waste management requires engagement with a large number of companies and needs to address the specific challenges offered by airside safety and security issues arising from the transfer of materials across the airside-landside boundary. For these reasons, a comprehensive site-wide waste management is the most economically and operationally effective approach, with the airport operator as the only corporate entity leading on the development of strategy, management, monitoring and reporting systems.

The principles of what is known as the "waste management hierarchy" (*Waste Framework Directive* 2008/98/EC) seek to:

- reduce the production of wastes in the first instance;
- maximise opportunities for the reuse and recycling of materials;
- minimise the amount of waste that is subsequently disposed of in landfills.

Waste key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.14

SHEETS

Code	Name	Weight
WM.1	Design to provide storage and collection of recyclables	0.26
WM.2	Design for deconstruction, reuse and recycling	0.26
WM.3	Select recucled, bio-based and reapidly renewable materials	0.22
WM.4	Select materials with high design service life, minimising maintenance and replacement cycles	0.26

REGULATORY FRAMEWORK

International

FAA (2008) Management of airport industrial waste

ISO 11932: 1996, Activity measurements of solid materials considered for recycling, reuse or disposal as non-radioactive waste

ISO 14021: 1999, Environmental labels and declarations – Self-declared environmental claims

ISO 14020: 2000, Environmental labels and declarations – General principles

ISO 14025: 2006, Environmental labels and declarations – Type III declarations – Principles and procedures

ISO 14040: 2006, Environmental management – Life cycle assessment – Principles and framework

ISO 14044: 2006, Environmental management – Life cycle assessment – Requirements and guidelines

ISO 21930: 2007, Sustainability in building construction – Environmental declaration of building products

ISO 21931 - 1: 2010, Sustainability in building construction - Framework for methods of assessment of the environmental performance of construction works – Part 1: Builsings

ISO 11932: 1996, Activity measurements of solid materials considered for recycling, reuse or disposal as non-radioactive waste

ISO 37120: 2014, Sustainable development of communities – Indicators for city services and quality of life

European

Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on waste

Regulation (EU) No 305/2011 of the European Parliament and the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

REFERENCES

European Commission (2005) Thematic strategy on the sustainable use of natural resources, COM(2005) 670 final

FAA (2011) Hazardous waste disposal guidance, http://www.faa.gov

FAA (2012) Recycling, Reuse and Waste Reduction at Airports, http://www.faa.gov

IMPACT (Integrated Material Profile And Costing Tool), www.impactwba.com

WASTE MANAGEMENT & MATERIALS

WM.1	**Design to provide storage and collection of recyclables**	
Airside	Master Plan	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	Technology	Refurbishment

Intent

To recognise and encourage the provision of dedicated storage facilities for a building's operational-related recyclable waste streams, so that this waste is diverted from landfill or incineration.

Related requirements

ER.4_Design infrastructure and buildings to minimise carbon and greenhouse gas emissions

Performance Indicator

Percentage of recycled materials

Recommended strategies

- Audit waste streams to determine the waste baseline
- Provide recycling containers in airport parking lots
- Designate an area for recyclable collection and storage that is appropriately sized and located in a convenient area. These areas would likely be designed and sized differently depending on the ultimate use and waste stream of the facility (e.g., terminal, airfield, office, airlines, concessionaires, cargo, hangar, etc.)

Regulations

FAA (2008) Management of airport industrial waste

Standards

ISO 11932: 1996, Activity measurements of solid materials considered for recycling, reuse or disposal as non-radioactive waste

References

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

WASTE MANAGEMENT & MATERIALS

WM.2	Design for deconstruction, reuse and recycling	
Airside	Master Plan	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Reuse building materials and products to reduce demand for virgin materials and reduce waste, thereby lessening impacts associated with the extraction and processing of virgin resources.

Related requirements

→ ER.4_Design infrastructure and buildings to minimise carbon and ghg emissions

← WM.3_Select recycled, bio-based and rapidly renewable materials

← WM.4_Select materials with high design service life, minimising maintenance and replacement cycles

Performance Indicator

Percent of total construction and demolition waste diverted from a landfill or incinerator

Recommended strategies

- Determine what design elements and infrastructure are needed to facilitate efficient waste reduction, recycling and reuse during operation.
- Re-use project waste as a resource to another project, which may include concrete, asphalt, land and clearing debris, and building components
- Consider reuse of existing, previously occupied buildings, including structure, envelope and elements and infrastructure.
- Consider structure and component lifecycle
- Where approved and appropriate, consider the use of Warm Mix Asphalt (WMA) for paving, which allows for the use of higher quantities of recycled asphalt pavement

Regulations

Regulation (EU) No 305/2011 of the European Parliament and the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

Standards

ISO 21931 - 1: 2010, Sustainability in building construction - Framework for methods of assessment of the environmental performance of construction works – Part 1: Builsings

References

FAA (2012) Recycling, Reuse and Waste Reduction at Airports

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment Method (BREEAM)

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual,

- Evaluate opportunities for application of deconstruction techniques - Implement deconstruction planning and techniques into all demolition activities. Careful and planned deconstruction of a facility can provide sustainable benefits related to disposal, reuse of materials, etc. - Designing structures with modular, reusable, easily recyclable, and de-constructible components. - Detail connections for disassembly; Detail connections for future expansion or downsizing. - Create flexible systems, spaces and infrastructure to enhance resource efficiency related to future uses, upgrades and expansions and maximize the life cycle of installed materials. - Design structures that are flexible, for future use, modular, to be structurally reconfigured (to either expand or downsize) and made of parts designed to be easily removed and reused; - Design for movable or demountable partition systems - Design for current needs with the ability to expand into the future. Do not oversize components during initial design phase to account for future build-out. - Design HVAC system in such a way that it is flexible to expand or downsize it depending on the future need of the space.	version 3.2, 2014, Chicago Department of Aviation (CDA) Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA) Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

WASTE MANAGEMENT & MATERIALS

WM.3	**Select recycled, bio-based and rapidly renewable materials**	
Airside	Master Plan	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Recognise and encourage the specification and procurement of responsibly sourced materials for key building elements and the selection of sustainable products for construction and retrofit projects that reduce waste and conserve production- and-distribution related resources and energy.

Related requirements

⇨ ER.4_Design infrastructure and buildings to minimise carbon and greenhouse gas emissions

⇦ WM.2_Design for deconstruction, reuse and recycling

Performance Indicator

Percent of total materials (as a portion of total material cost) sourced for any retrofit or expansion project consisting of environmentally preferable construction

Recommended strategies

- Establish a project goal for locally sourced materials, and identify materials and material suppliers that can achieve this goal. During construction, ensure that the specified local materials are installed and quantify the total percentage of local materials installed. Consider a range of environmental, economic and performance attributes when selecting products and materials.
- Establish a project goal for recycled content materials, and identify material suppliers that can achieve this goal. During construction, ensure that the specified recycled content materials are installed. Consider a range of environmental, economic and performance attributes when selecting products and materials.

Regulations

Regulation (EU) No 305/2011 of the European Parliament and the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

Standards

ISO 14021: 1999, Environmental labels and declarations – Self-declared environmental claims

ISO 14020: 2000, Environmental labels and declarations – general principles

ISO 14025: 2006, Environmental labels and declarations – Type III declarations – Principles and procedures

ISO 21930: 2007, Sustainability in building construction – Environmental declaration of building products

References

European Commission (2005) Thematic strategy on the sustainable use of natural resources, COM(2005) 670 final

- Establish the appropriate project goal for **renewable** materials utilization. Consider temporary construction materials.
- Provide a fact sheet to designers that includes available recycled content materials and the organization's target for each material

WASTE MANAGEMENT & MATERIALS		
WM.4	**Select materials with high design service life, minimising maintenance and replacement cycles**	
Airside	Master Plan	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Recognise and encourage adequate protection of exposed elements of the building and landscape, therefore minimising the frequency of replacement and maximising materials optimisation.

Related requirements

→ ER.4_Design infrastructure and buildings to minimise carbon and ghg emissions

→ EN.3_Design and upgrade buildings to reduce energy consumption

← WM.3_Select recycled, bio-based and rapidly renewable materials

Performance Indicator

Percent of total materials (as a portion of total material cost) sourced for any retrofit or expansion project consisting of environmentally preferable construction

Recommended strategies

- Review engineering standards for building systems equipment subject to period maintenance or replacement (e.g., air handler motors and belts, pumps and valves, luminaries or switches) to identify potential durability upgrades that would measurably reduce life cycle maintenance costs

- Avoid products that require frequent replacement or regular maintenance to reduce future waste, including landscaping materials

Regulations

Regulation (EU) No 305/2011 of the European Parliament and the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

Standards

ISO 14020: 2000, Environmental labels and declarations – General principles

ISO 14025: 2006, Environmental labels and declarations – Type III declarations – Principles and procedures

ISO 14040: 2006, Environmental management – Life cycle assessment – Principles and framework

ISO 14044: 2006, Environmental management – Life cycle assessment – Requirements and guidelines

References

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment

- Specify more durable, longer lasting materials and finishes to extend material life and reduce maintenance requirements	Method (BREEAM) Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED) IMPACT (Integrated Material Profile And Costing Tool) IMPACT is a specification and database for software developers to incorporate into their tools to enable consistent Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). www.impactwba.com

III.6.2.6_WATER POLLUTION REDUCTION | WP

SUMMARY

This category encourages the adoption of design and technological strategies to reduce the effect of stormwater on the surface and ground water basins.

DRIVERS FOR ACTIONS/CONSTRAINTS

The primary drivers for action to prevent water pollution include regulatory requirements (aquifers protection, public health, water resource shortage), the need to minimise operating costs, and - in the event of spills - associated environmental cleanup charges.

KEY STRATEGIES HIERARCHY

As environmental regulations tighten, the ability to monitor for aviation contamination has become essential. In order to monitor the quality of water and its levels of contamination, sensors are installed at various locations around the airport. In order to implement effective measures of prevention it is essential to determine which areas of the airport are likely to be subject to different risks in terms of surface and groundwater pollution. The different catchment areas that feed underground drainage systems around the airport estate are affected by the geographic distribution of aprons, taxiways, runways, terminal buildings, and maintenance and other infrastructure across the site and are therefore linked to the overall infrastructure design.

The effective control of water contamination depends on:

- The development of specific operational practices
  - Strict handling procedures
  - Spill response procedures
  - Strict storage and handling procedures
  - Specific, clear and well documented handling procedures
  - Training, awareness building, motivation
- The selection of appropriate materials for airport related activities (such as de-icing procedures)
  - Low impact products
  - Use according to instructions
  - Just in time use
  - Alternatives to use chemicals
- The design of infrastructure which related to

  (Drainage infrastructure)
  - Catchment areas feed underground drainage system
  - Settlement tanks
  - “First flush” collection
  - Automatic monitoring and flow diversion

  (Diversion to mains drainage)

- Many airports divert dirty water into the mains sewerage system for treatment offsite
- Many chemical pollutants from airport activities not appropriate for such an approach so pre-treatment on site may be necessary

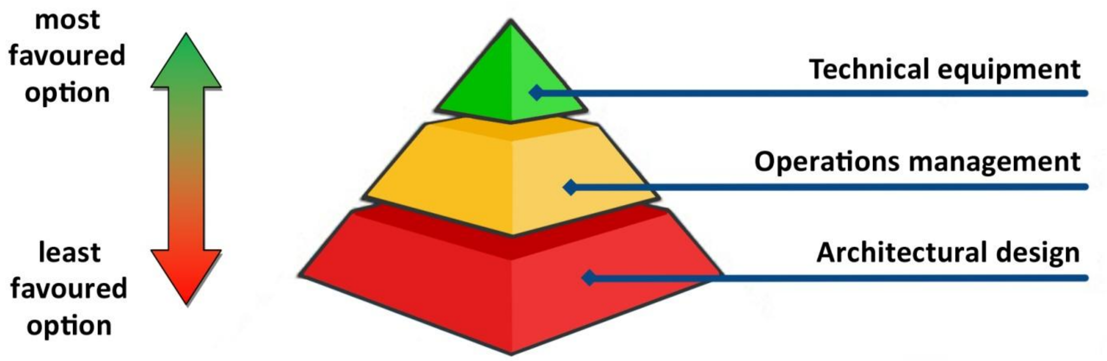
(Water recycling)

- Water recycling plants can process water for reuse
- Not all pollutants can be handled
- Financial implications

(Sustainable solutions)

- Surface water runoff from hard standing through "natural" clean up systems (e.g. microbes "seeded" onto crumpled car tyres; reed beds)

Water management key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.17

SHEETS

Code	Name	Weight
WP.1	Design to reduce stormwater quantity	0.50
WP.2	Design to improve stormwater quality	0.50

REGULATORY FRAMEWORK

International

FAA (2008) Management of airport industrial waste

ISO 15175: 2004, Soil quality – Characterisation of soil related to groundwater protection

ISO 5667-22: 2010, Water quality – Sampling – Part 22: Guidance on the design and installation of groundwater monitoring points

European

Directive 2006/118/EC of the European Parliament and the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration

REFERENCES

Airport Council International (2009) *Policies and Recommended Practices Handbook 2009*;

Airport Cooperative Research Program (2011) *A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning*

EPA (2009) Technical guidance on implementing the sotrmwater runoff requirements, Washington

European Commission (2008) Environment report – Water, Groundwater protection in Europe. The groudwateer directive – consolidating the EU regulatory framework

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment Method (BREEAM)

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, version 3.2, 2014, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

WASTE MANAGEMENT & MATERIALS

WM.1	Design to reduce stormwater quantity	
Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	**Technology**	**Refurbishment**

Intent

To avoid, reduce and delay the discharge of rainfall to public sewers and watercourses, thereby minimising the risk and impact of localised flooding on and off-site, watercourse pollution and other environmental damage.

Related requirements

➡ WT.3_Design to maximise water harvest, recycle and reuse

➡ WP.2_Design to improve stormwater quality

⬅ BL.4_Design and technologies to reduce light pollution

Performance Indicator

Performance is evaluated based on the number of performance actions pursued that address the requirement

Recommended strategies

- Locate parking areas below building footprint. Remove unnecessary pavement from site
- Utilise pervious pavement for roadways, shoulders, non-traffic pavements, maintenance roads, utility yards, airside and landside parking facilities
- Use natural fiber geotextiles (permeable fabrics) that are biodegradable
- Use vegetated green-roofs to intercept and treat stormwater; Install landscape to reduce runoff
- Design the project site to maintain natural stormwater flows by promoting infiltration. Specify vegetated roofs, pervious

Regulations

Directive 2006/118/EC of the European Parliament and the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration

References

New Construction. Non-domestic Buildings, Technical Manual 2014, Building Research Establishment's Environmental Assessment Method (BREEAM)

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, version 3.2, 2014, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program

paving, and other measures to minimize impervious surfaces. - Because many airside pavements have the potential for deicing fluid and jet fuel contamination, technologies that increase infiltration to the subsurface are not used. On landside projects, or for areas not subject to aviation-related contaminants, these methods are encouraged	(ACRP) EPA (2009) Technical guidance on implementing the sotrmwater runoff requirements, Washington

WASTE MANAGEMENT & MATERIALS

WM.2	Design to improve stormwater quality	
Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Reduce or eliminate stormwater pollution by treating and infiltrating stormwater on-site.

Related requirements

⇦ WP.1_Design to reduce stormwater quantity

⇨ WT.3_Design to maximise water harvest, recycle and reuse

⇦ BL.2_Design infrastructure and buildings not to be attractive to some animal species

Performance Indicator

Performance is evaluated and points are awarded based on the number of performance actions pursued.

Recommended strategies

- Minimize impervious area on the site – this will reduce the amount of stormwater that must be treated. Use vegetated green-roofs to intercept and treat stormwater
- Use detention basins, detention ditches, ditch checks and other BMPs for effective first-flush treatment
- Design for bioswales along roadway and parking areas to encourage groundwater infiltration of stormwater runoff. On airside projects, these strategies should not encourage animal habitat
- Incorporate underground infiltration BMPs, such as dry wells or perforated drainpipe on airside projects. These methods avoid creating inundated areas, which attract wildlife
- Harvest stormwater for irrigation of landscaping. This avoids both the cost of stormwater treatment and water for

Regulations

Directive 2006/118/EC of the European Parliament and the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration

FAA (2008) Management of airport industrial waste

Standards

ISO 15175: 2004, Soil quality – Characterisation of soil related to groundwater protection

ISO 5667-22: 2010, Water quality – Sampling – Part 22: Guidance on the design and installation of groundwater monitoring points

References

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

European Commission (2008) Environment report – Water, Groundwater protection in Europe. The groudwateer directive – consolidating the EU regulatory framework

irrigation.
- Minimise current treatment of stormwater by reducing runoff. Utilize engineered wetlands for stormwater treatment.
- Develop stormwater collection and rain harvesting systems for treatment prior to reuse or discharge.
- Isolate and collect aircraft de-icing fluid runoff

III.6.2.7_BIODIVERSITY PRESERVATION & LAND USE | BL

SUMMARY

Airports have been usually built out from the urban conurbation in open countryside or in "green belt" areas, in order to have land availability for future expansion and reduce impacts on the nearest cities and communities. The increasing awareness about habitats protection and biodiversity and the associated evolution of international and national regulations.

DRIVERS FOR ACTIONS/CONSTRAINTS

The potential threats to the ecological value of local habitats and eco-systems represent a constraint for airport operational capacity and infrastructure expansion in the surrounding territory.

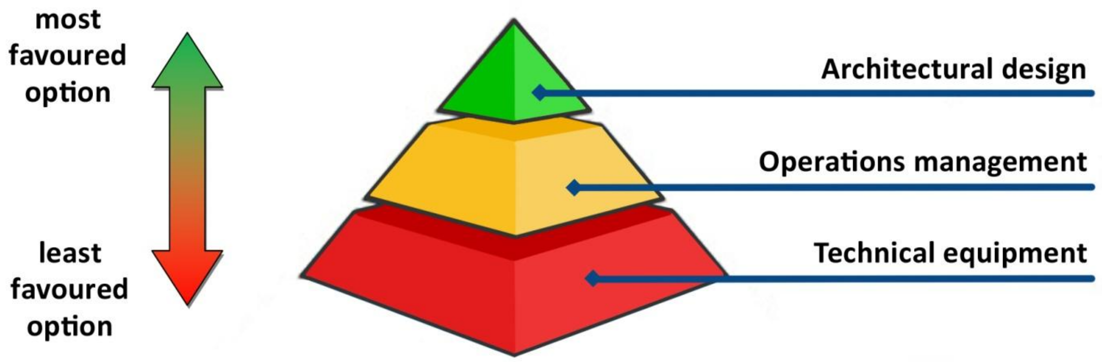
KEY STRATEGIES HIERARCHY

Sustainable development would require that airports compensate for their adverse ecological impacts through landscape and habitat management, mitigation, and compensation programs. The challenge of protecting biodiversity while facilitating airport growth is exacerbated, however, by the issue of bird hazards to aircraft. Airports attract a wide range of wildlife which represent a threat to aviation and need to be controlled. Land uses such as landfills, lakes, marshes, wetlands, reservoirs, etc., may attract wildlife which should be discouraged or if unavoidable, should be managed, keeping aviation safety as a priority. There can therefore be a conflict between the development of ecological mitigation measures and aviation safety, an issue that has arisen at a number of airport developments.

Within the airport boundary control is best exercised by denying wildlife access through the effective use of fences and other barriers. However, main measures dealing with habitat protection and biodiversity, are related to landscaping. Habitat management, including grass management, should be employed to minimize the attractiveness of airport lands to wildlife. Insofar as possible, wet land and stagnant water on aerodromes should be drained. Buildings can also provide numerous opportunities for roosting and or nesting by birds and are often inhabited by small mammals. Analysis of buildings can identify places that can be used by wildlife. The elimination of these potential shelters will decrease the numbers of animals present. Aerodrome operators may need to obtain advice from specialists working in conjunction with local agronomists on the seed mixes to be used for planting on the airfield. The mix should permit development of slow-growing plants producing a minimum of seeds, to avoid providing food for birds, yet with sufficient regeneration to maintain good soil coverage. Climate change patterns should be also considered when choosing species to be implanted.

Based on on the scientific literature and the evaluation of the answers to the survey, a hierarchy which synthetises the strategies to reduce noise disturbance is proposed:

Biodiversity and land use key strategies hierarchy



CATEGORY OVERVIEW

Overall category weight	0.10

SHEETS

Code	Name	Weight
BL.1	Design the layout of infrastructure to avoid destruction of sensitive habitats	0.28
BL.2	Design infrastructure and buildings not to be attractive to some species	0.28
BL.3	Landscape and design to minimise land use and reduce heat island effect	0.22
BL.4	Design and technologies to reduce light pollution	0.22

REGULATORY FRAMEWORK

International

FAA (2007) Advisory Circular 150/5200-33 Hazardous wildlife attractants on or near airports

ISO 37120:2014, Sustainable development of communities — Indicators for city services and quality of life

European

Commission staff working document - Annex to the Communication from the Commission - Halting the loss of biodiversity by 2010 - and beyond - Sustaining ecosystem services for human well–being {COM(2006)216 final} - Impact assessment /* SEC/2006/0607 */

"Birds Directive" (2009/147/EC) and the "Habitats Directive" (92/43/EEC).

Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora

Directive 2009/147/EC on the conservation of wild birds (see www.ec.europa.eu)

Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending directive 2004/35/EC

European Commission (2006) COM(2006)231 final "Thematic Strategy for Soil Protection"

European Commission (2015) COM(2015) 478 final "The mid-term review of the EU biodiversity strategy to 2020"

REFERENCES

ACI - Airport Council International (2009) Policies and Recommended Practices Handbook 2009, Montreal

European Environment Agency (2012) JRC Reference Report "The state of the soil in Europe"

BIODIVERSITY PRESERVATION & LAND USE

BL.1	Design the layout of infrastructure to avoid destruction of sensitive habitats

Airside	Master Plan	New Construction
Terminal /Buildings	Building design	Development
Landside	Technology	Refurbishment

Intent

Promotes the preservation of undeveloped land by prioritising and making efficient use of existing infrastructure, rehabilitating contaminated sites, and protecting land for future aeronautical use.

Related requirements

⇦ NA.1_Design airside layout to reduce noise emissions

⇨ NA.2_Provide physical mitigation barriers between operating areas and the surroundings

⇨ WT.1_Lanscape and design to reduce water use

⇦ WP.1_Design to reduce stormwater quantity

⇨ WP.2_Design to improve stormwater quality

Performance Indicator

Level of use of the intervention area (site)

Recommended strategies

- Build on previously developed sites, or one close to existing infrastructure
- Maximize use of contaminated or brownfield sites to reduce pressure on undeveloped land
- Perform a topographical analysis of the site. Strive to maintain natural topographic configuration.
- Identify landscape features for preservation during site design. Design your project around these features.
- Preserve natural water features and wetlands on the site as appropriate. These features provide excellent wildlife habitat, cooling properties and aesthetic benefits

Regulations

Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora

Directive 2009/147/EC on the conservation of wild birds

Standards

ISO 14001:2015, Environmental management systems — Requirements with guidance for use

ISO/DIS 19204, Soil quality — Procedure for site-specific ecological risk assessment of soil contamination (TRIAD approach)

References

Building Research Establishment Environmental Assessment Methodology (BREEAM)

Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines, Los Angeles World

- Introduce drainage features as part of development if site is previously developed and has no natural drainage features - Provide open space area(s) that are equal to or greater than the development area - Develop a balanced earthwork plan and retain the maximal excavated earth on-site	Airports (LAWA) Prototype Airport Sustainability Rating System - Characteristics, Viability, and Implementation options, Airport Cooperative Research Program (ACRP)

BIODIVERSITY PRESERVATION & LAND USE

BL.2	Design infrastructure and buildings not to be attractive to some animal species

Airside	Master Plan	New Construction
Terminal /Buildings	Building design	Development
Landside	Technology	Refurbishment

Intent

Wildlife and habitat protection promotes the preservation, creation, and restoration of ecologically sensitive lands and biodiversity, particularly species of concern on airport-owned property.

Related requirements

→ NA.2_Provide physical mitigation barriers between operating areas and the surroundings

← WP.1_Design to reduce stormwater quantity

→ WP.2_Design to improve stormwater quality

← BL.1_Design the layout of infrastructure to avoid destruction of sensitive habitats

Performance Indicator

Positive trends indicating decreasing total annual number of wildlife strikes per 10,000 aircraft movements.

Recommended strategies

- Choose vegetation that does not attract hazardous wildlife when planting
- Avoid creation of open water features on or near airfield sites
- For stormwater management, consider use of perforated underground drains or dry wells to provide infiltration.
- In areas with height restriction, use low growth plants and trees
- Install Kevlar bird deterrent wires or other mechanisms to prevent waterfowl from using area water bodies

Regulations

FAA AC 150/5200-33B, *Hazardous Wildlife Attractants on or near Airports*, these land uses often include: (a) solid waste landfills; (b) existing or proposed dredge spoil containment areas; (c) wastewater treatment facilities; (d) wetlands, wildlife refuges; or (e) other land uses that attract wildlife that is hazardous to aviation.

References

ACI - Airport Council International (2009) Policies and Recommended Practices Handbook 2009, Montreal

Building Research Establishment Environmental Assessment Methodology (BREEAM)

Sustainable Airport Planning, Design and Construction Guidelines, Los Angeles World Airports (LAWA)

Prototype Airport Sustainability Rating System - Characteristics, Viability, and Implementation options, Airport Cooperative Research Program (ACRP)

BIODIVERSITY PRESERVATION & LAND USE		
BL.3	**Landscape and design to minimise land use and reduce heat island effect**	
Airside	**Master Plan**	**New Construction**
Terminal /Buildings	**Building design**	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Reduce heat islands (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human and wildlife habitat.

Related requirements

⇨ ER.2_Reduce parking footprint

⇨ WM.3_Select recycled, bio-based and rapidly renewable materials

⇦ WP.1_Design to reduce stormwater quantity

⇦ BL.1_Design layout to avoid destruction of sensitive habitats

Performance Indicator

Performance is evaluated based on the number of performance actions pursued that address the requirement

Recommended strategies

- Prioritise installation of equipment with high solar reflectance or high albedo
- Install vegetation surfaces on roofing; Install a vegetated green-roof system that considers drought- resistant vegetation and does not attract wildlife
- Increase shaded and covered areas for parking lots and paved areas
- Use metal roofs with industrial grade coating with high-reflectance (non-glare) and emittance
- Employ strategies, materials and landscaping techniques that reduce heat absorption of exterior materials.
- Utilise a combination of vegetated and high-albedo surfaces.
- Minimize paved-over surfaces, especially impervious

Standards

ASTM E-1980-01 – solar reflectance index (SRI)

ISO 21929-1:2011, Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings

References

Building Design and Construction, version 4, 2015, Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, version 3.2, 2014, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines for implementation on All Airport Projects, version 5.0, 2010, Los Angeles World Airport (LAWA)

Prototype Airport Sustainability Rating System. Characteristics, Viability, and Implementation options, report 119, 2014, Airport Cooperative Research Program (ACRP)

pavements; Maximize high-albedo pavements - Provide shade to cover dark impervious surfaces using native or climate-tolerant trees and large shrubs, vegetated trellises or other exterior structures supporting vegetation. - Substitute vegetated surfaces for impervious surfaces. - Landscape to reduce heat through plant transpiration. - Use open grid pavement systems. - Develop high-albedo structural roof to cover dark pavements and parking spaces	

BIODIVERSITY PRESERVATION & LAND USE		
BL.4	**Design and technologies to reduce light pollution**	
Airside	**Master Plan**	**New Construction**
Terminal /Buildings	Building design	**Development**
Landside	**Technology**	**Refurbishment**

Intent

Promotes the efficient management of illumination at night, thereby reducing resource consumption and improving conditions at nearby residential communities.

Related requirements

⇨ ER.2_Design to reduce outdoor energy consumption

Performance Indicator

Performance is evaluated based on the number of performance actions pursued that address the requirement

Recommended strategies

- Adopt light pollution plan, siting and design best practices where possible while maintaining proper illumination
- Adopt site lighting criteria to maintain safe light levels while avoiding off-site lighting and night-sky pollution
- Limit lighting in protected ecological areas to mitigate lighting impacts on wildlife.
- Model the site lighting using a computer model.
- Design for monitoring of maximum candela value.

- Develop light shielding techniques on parking structures and roads
- Focus light toward the earth to minimize night-sky pollution.
- Consider full cutoff luminaries, low-reflectance, non-specular surfaces and low angle spotlights for roadway and building lighting.
- Install motion activated parking lot lights
  *Does not include lighting vital to airport safety

- Use High Pressure Sodium (HPS) lamps instead of Metal Halide (MH) lamps, where acceptable. HPS lamps produce

References

Building Research Establishment Environmental Assessment Methodology (BREEAM)

Leadership in Energy and Environmental Design (LEED)

Sustainable Airport Manual, Chicago Department of Aviation (CDA)

Sustainable Airport Planning, Design and Construction Guidelines, Los Angeles World Airports (LAWA)

Prototype Airport Sustainability Rating System - Characteristics, Viability, and Implementation options, Airport Cooperative Research Program (ACRP) more lumens per watt, have less mercury content per lamp and have a greater average rated life expectancy than MH lamps, which could potentially decrease maintenance and replacement costs.

- Evaluate smart-lighting control systems and LED light technologies

Conclusions

a. Summary of key findings

The research developed methods and tools for the performance evaluation and the definition of design and technological strategies related to the environmental sustainability of airport infrastructures.
The general objective of the research was to identify the environmental issues related to airport operations and infrastructure development in order to define the criteria for the evaluation of the architectural and technological strategies complying with the sustainability requirements since the early stage of airport planning and conception. The key stages to pursue this objective were to:

- Understand and outline the airport development scenario in order to identify the main factors influencing airport design and recognise the environmental issues and how they act as a constraint to airport growth and development.
- Define a framework of performance requirements aimed at reducing and minimising those issues through architectural and design strategies.

The final objective of the research was to develop an evaluation system that associates to each environmental performance requirement a set of architectural and technological strategies and a 'weight' to measure and compare those strategies and guide the decision-making process since the early stages of project design development.

The analysis of the development scenario of the airport field and of the European policies and research strategies for this sector has allowed a thorough assessment of the development of the industry with particular reference to the European situation characterized by steady levels of air traffic growth and the complexity of the territory and the resulting environmental impacts that already constraint the opportunity for the building of new infrastructure and the expansion of the existing ones. The awareness of the characteristics that affect the airport design have also made clear the role of architectural design in an area in which various stakeholders and professionals contribute to the definition of the final project design. This stage of the research has also allowed to establish the role of architectural design in pursuing environmental sustainability goals: understand where the typological and technological strategies may affect the magnitude of an impact or to ensure its reduction, was crucial to the subsequent analysis of the environmental issues arising from airport infrastructure.

The currently most widely spread certification systems represented the starting point for the creation of a specific framework for airports. In particular it was noted that BREEAM and LEED have strong recognition across airports and airport stakeholders. Multiple airports have BREEAM/LEED-certified terminal buildings. BREEAM and LEED do not currently address horizontal infrastructure such as airport runways and other airside and landside-related assets. Moreover there is

not a specific reference to infrastructure such as airports and this limits the applicability of the system.
A number of larger hub airports and airport authorities have based their own airport-specific guidance those rating systems. Each independent airport-designed system (such as those developed by the Los Angeles World Airports and the Chicago Department of Aviation) is designed to support the scale and functions of the unique airport it serves and therefore may have limited applicability to the medium and small airports that might benefit from borrowing the approach.
Finally the ACRP's prototype represents the first attempt to define an airport-related rating systems which includes environmental, social and economic aspects and look at design strategies as well as operations management, technical equipment, staff training and community engagement (to name the most relevant). The limit of this system are related to the variety of parameters to consider and the lack of a complete system of evaluation.
The objective of this research was to contain the characteristics and parameters to consider in favour of a definite and clear objective: identify the environmental issues arising from airport operations and infrastructure development and develop methods and tools to evaluate performance requirements based on architectural and technological strategies.

During the analysis stage of the environmental issues strategies for minimising those issues have been identified. In addition to design strategies, operations management and technical equipment have been taken into consideration. It was evident that the architectural design has in many cases a lower effectiveness and applicability than other strategies (generally preferred by the airport operators). On the other hand the design of the infrastructure – which may minimise the airport environmental impacts - may as well increase the magnitude of those impacts.

For this purpose, a survey have been developed and sent to engineers, architects and environmental experts working in the airports' technical departments, who understand the limit to the airport design due to the involvement of different stakeholders and professionals from multi-disciplinary fields. The feedback obtained from the survey confirmed what was already mentioned in the analysis stage allowing to establish priorities among the various typology of strategies proposed, and especially to create an evaluation system between the various environmental issues and the proposed requirements. However, from the analysis of the results discrepancies of some of the respondent evaluations have been noticed. Those discrepancies made clear that a unique system of evaluation for each airport is not possible because the environmental problems and the design strategies possible vary based on the location, the airport typology, its development scenarios, the communities involved.

In the proposal stage methods and tools for managing the project design development of green airport design have been defined. For the reasons illustrated so far, the product of the research is subjected to changes and implementations. The presented research, far from established as unchangeable and definitive answer to the scientific problem statement, is a proposal who may be developed in further lines of research.

A pilot case study is currently under study in collaboration with the Iasi International Airport (Romania) and the Centre for Aviation, Transport and the Environment (Manchester Metropolitan University).

b. Emerged limitations and critical aspects

The research limitations are linked to the need to focus on some aspects leaving others apart, depending on the available time and the skills acquired.
In particular, during the investigation and analysis stages, it will be necessary an extension of the examples and case studies considered and the specific evaluation systems developed by consultant as ARUP and others. Other models of evaluation of environmental performance have been also developed by international organizations and institutions such as Eurocontrol. It is therefore necessary to investigate those systems to integrate the most innovative tools of analysis and evaluation with the model developed in this research.

A further limitation emerges from the proposed survey: the sample identified – although significant – represents a small percentage of European airports which cannot be considered sufficient for the development of the final model. Moreover, as outlined in the previous section, the model is suitable to be adapted to different airport typology and situation. The survey should therefore provide evidence of that variety and include a more wide range of participants.

c. Contribution to knowledge

The result of this study is the application of sustainability criteria in airport design through the support of innovative operational tools. The research defines specific methods and tools enabling both design project control and sustainability appraisal. This type of project design organisation enables the management of the sustainability requirements and it also ensures the consistent verification of all project levels of development, from the project conception to the construction and operation and maintenance.
Withint the *Green Airport Evaluation Design* (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 preservation and land use.

Each category contains a different number of requirements and design specifications. A fact sheet is provided for each requirement with information regarding: the purpose and definition of the requirement, architectural and technological strategies for the minimization of the environmental impacts, specific standards and regulations.
The GrADE method and 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 managers to define strategies and anticipate decisions to enhance sustainable airport infrastructure design.

d. Recipients and policy recommendations

European and national aviation regulatory organizations (e.g. ACI – Airport Council International and ENAC – Ente Nazionale Aviazione Civile) – which are responsible for the authorisation, control and coordination of airport intervention programmes – are the main recipients of this research. They may also be involved in the funding and collaboration to the future development of the research products.
Other recipients are the airport operators, designers and consultants that can use the GrADE tools for the identification of design and technological strategies addressing environmental sustainability.
Academics and researcher in the Architectural Technology field may also employ the methodologies proposed in this research to develop methods and tools suitable for other building typologies.

e. Research critique and further lines of enquiry

Following further verification of the research results, the framework of the suggested design and technological strategies could be integrated with the technical, operational and management strategies complying with the reduction and elimination of the environmental impacts. With this in mind, the final model may be implemented on a national and European level as a recognised system of verification and accreditation (such as the Airport Carbon Accreditation which assesses and certifies various levels of sustainability regarding the reduction of carbon emissions).

f. Further post-doc research developments

Future research scenarios will be characterised by the contribution of multi-disciplinary academic fields and direct contact with the aviation industry and with European and international regulatory organisations.

In order to achieve higher levels of sustainability the proposed method and tools represent a good practice for the airport system which is always open to revisions and implementations imposed by the continuous increase of passengers flows, development of technology, updating of standards and evolution of the sustainability design approach itself. The next step is the integration between the decision-making and design process in the airport field already green aimed and BIM (Building Information Modelling) simulation emerging in the international panorama. Possible future developments of the research are then aimed at the elaboration of green performance specifications integrated with Building Information Modeling & Management (BIM(M)) suitable for the airport industry.

APPENDIX A - Survey

GrADE survey - The role of architecture in airport sustainability

Green Airport Design Evaluation (GrADE) - Doctoral research survey

GrADE is a doctoral research study focused on the process of evaluation of project compliance with green building requirements during preliminary stages of the airport design process. The primary aim of the research is to develop methods and tools to check and evaluate sustainability design performances during the early stage of airport design and to inform the decision making process.

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.

The GrADE's method will be based on the development of environmental sustainability indicators that would inform a site wide approach to the design of airport infrastructure. The proposed methods and tools will create new opportunities for aviation regulatory organisations and airport managers to define strategies and anticipate decisions to enhance sustainable airport infrastructure design.

The GrADE research is carried out within the Dipartimento di Architettura of the Università degli Studi di Firenze (Italy) under the supervision of prof. Ilaria Garofolo and in collaboration with professor Callum Thomas from the Centre of Aviation, Transport and the Environment (CATE) of the Manchester Metropolitan University (UK).

1

GrADE survey - The role of architecture in airport sustainability

Aim of the survey - Developing a sustainability evaluation framework

Dear Respondent,

The purpose of this survey is to define and evaluate the priorities among a set of architectural design and technological strategies to minimise and/or eliminate environmental impacts arising from airport infrastructure development and operations.

The survey is addressed to the Airport Planning, Infrastructure Development, Environmental, and Technical Managers of the European air transport network. By participating, they can provide a structured and competent support as regard the good practices for the sustainable airport infrastructure planning and design.

Your participation in this study is voluntary and anonymous. There is no time limit, although it is recommended to have at least 20 minutes to complete the survey.

Remember that the results of this study may be published, though your identity and that of your airport will remain confidential (unless you would like to promote a case study example from your airport). Each survey will be coded with a number, not your name. You will be informed just about your own code so you will be able to check own correspondence to other airports in the overall results of the survey. Your code will not be released to anyone else.

Thank you for taking the time to complete this survey. Your participation will be useful for the *GrADE* research.

Please feel free to contact me for any enquiry regarding the *GrADE* survey and/or asking more information about the research.

Best Regards,
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2

GrADE survey - The role of architecture in airport sustainability

Instructions and Consent

The survey is composed of three parts:

- Part I: Respondent and airport profile
You will be asked to provide your contact data and professional profile, and information about the airport you are currently working in;
- Part II: "Airport Environmental Sustainability" - Perception of the Issues
You will be asked to answer some multiplie-choice questions and assign values regarding the proposed issues (sustainability, environmental issues constraining airport growth, green building rating systems).
- Part III: "Sustainability Evaluation" - Evaluating strategies for Green Airport Design
You will be asked – through some multiple-choice questions – to evaluate environmental issues that constraints your airport infrastructure and operational capacity growth and whether you are using infrastructure design to minimise and/or eliminate those environmental impacts.
You will be also asked to assign value to suggested strategies for the minimisation of airport environmental issues.

The deadline for filling-in this survey is October 30th, 2015. Surveys that will be completed after this date will be considered for future pubblications, but the results may not be included in the final doctoral thesis.

1. Will you participate in the survey?

Checking the "Accept" box indicates that you understand the nature of the study, and the means by which your identity will be kept confidential. Additionally, you confirm that your participation in the study is voluntary. If you do not wish to participate in the research study, please refuse to participate by checking on "Decline".

- ◯ Accept
- ◯ Decline

3

GrADE survey - The role of architecture in airport sustainability

Part I
Respondent Profile

2. Respondent profile and contact data

Name and surname	
Title (e.g. Eng., Arch., *etc.*)	
Current role	
e-mail address	

4

GrADE survey - The role of architecture in airport sustainability

Part I
Airport profile

3. Airport name and IATA code

4. In which range is the forecasted number of passengers?

Please feel free to provide only the information about the available forectsts.

	in 5 years (2020)	in 15 years (2030)	in 35 years (2050)
< 5.000.000 pax	☐	☐	☐
5.000.000 - 20.000.000 pax	☐	☐	☐
20.000.000 - 40.000.000 pax	☐	☐	☐
40.000.000 - 60.000.000 pax	☐	☐	☐
60.000.000 - 80.000.000 pax	☐	☐	☐
80.000.000 - 100.000.000 pax	☐	☐	☐
> 100.000.000 pax	☐	☐	☐

Please feel free to add a comment

5

5. Considering the airport infrastructure future development, which are the facilities that are planned to be modified (e.g. upgrade, refurbishment, new construction) in the short, medium and long-term period?

Please choose from the list only the fecilities that are planned to be modified.

	in 5 years (2020)	in 15 years (2030)	in 35 years (2050)
Runway/s	☐	☐	☐
Terminal building/s	☐	☐	☐
Rail/metro station	☐	☐	☐
Parking lots	☐	☐	☐
Other building facilities (office, hotels, conference centres, etc.)	☐	☐	☐
Systems and facilities for alternative and renewable energy production	☐	☐	☐
Systems and facilities for water harvesting and treatment	☐	☐	☐

Please feel free to add a comment and/or more information regarding your airport future development

6

GrADE survey - The role of architecture in airport sustainability

Part II
Airport environmental sustainability - Defining the issues

6. When evaluating factors affecting airport sustainability, how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that is extremely important.

	1	2	3	4	5
Business viability	◯	◯	◯	◯	◯
Environment protection and use of resources	◯	◯	◯	◯	◯
Operational capacity	◯	◯	◯	◯	◯
Community needs	◯	◯	◯	◯	◯

Please feel free to add a comment

7. Do you perceive environmental issues as a threat to your airport future growth?

◯ Yes

◯ No

Please feel free to add a comment

8. What environmental issues are currently constraining your airport growth?

For each issue please select a number between 1 and 5 where 1 means that it represent a very low level of constraint and 5 that it represent a very high level of constraint.

	1	2	3	4	5
Biodiversity and Habitat loss	◯	◯	◯	◯	◯
Carbon and greenhouse gas emissions	◯	◯	◯	◯	◯
Energy use	◯	◯	◯	◯	◯
Local air quality	◯	◯	◯	◯	◯
Noise	◯	◯	◯	◯	◯
Waste management	◯	◯	◯	◯	◯
Water pollution	◯	◯	◯	◯	◯
Water use	◯	◯	◯	◯	◯

Please feel free to add a comment

8

9. What environmental issues will constrain your airport growth over a medium-term period (15 years)?

For each issue please select a number between 1 and 5 where 1 means that it represent a very low level of constraint and 5 that it represent a very high level of constraint.

	1	2	3	4	5
Biodiversity and Habitat loss	○	○	○	○	○
Carbon and greenhouse gas emissions	○	○	○	○	○
Energy use	○	○	○	○	○
Local air quality	○	○	○	○	○
Noise	○	○	○	○	○
Waste management	○	○	○	○	○
Water pollution	○	○	○	○	○
Water use	○	○	○	○	○

Please feel free to add a comment

GrADE survey - The role of architecture in airport sustainability

Part II
Airport environmental sustainability - Defining the issues

10. A number of tools using environmental sustainability indicators have been developed in the last two decades. International green building rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), and others have been used as an effective structured framework for assessing building environmental performance and integrating sustainable development into airport design processes.

On what extent do you agree on the usefulness of a standardise system (such as BREEAM and LEED) as a framework to guide and define strategies and anticipate decisions to ease sustainable airport design?

Please select a number between 1 and 5 where 1 means that you don't agree and 5 that you strongly agree.

1	2	3	4	5
○	○	○	○	○

Please feel free to add a comment

11. Is your airport currently pursuing any environmental certification?

If yes, please specify which certification/s (e.g. LEED) and which level is aiming at (e.g. "gold").

If no, skip to the next question.

12. Has your airport achieved any environmental certification?

If yes, please specify which certification/s (e.g. LEED) and at which level (e.g. "gold").

If no, skip to the next pge.

10

GrADE survey - The role of architecture in airport sustainability

Part III
Airport environmental sustainability - Evaluating strategies for *Green Airport Design*

13. When evaluating strategies to minimise or eliminate environmental issues, which priority is assigned to the following categories?

For each category please select a number between 1 and 5 where 1 means that it represent a very low level of priority and 5 that it represent a very high level of priority.

	1	2	3	4	5
Biodiversity and Habitat preservation	○	○	○	○	○
Carbon emissions reduction and Air quality	○	○	○	○	○
Energy use	○	○	○	○	○
Noise abatement	○	○	○	○	○
Waste management and Use of materials	○	○	○	○	○
Water pollution	○	○	○	○	○
Water use	○	○	○	○	○

Please feel free to add a comment

11

GrADE survey - The role of architecture in airport sustainability

Part III
Airport environmental sustainability - Evaluating strategies for *Green Airport Design*

14. When evaluating strategies to minimise or eliminate NOISE issues how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	○	○	○	○	○
Technical equipment	○	○	○	○	○
Architectural design	○	○	○	○	○

Please feel free to add a comment.

15. When evaluating architectural design strategies to minimise or eliminate NOISE issues how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Design airside layout to reduce noise impact	○	○	○	○	○
Provide physical mitigation barriers between operating areas and the surroundings	○	○	○	○	○

Please feel free to add a comment and illustrate which architectural design strategies are you using.

12

16. When evaluating strategies to minimise CARBON EMISSIONS and enhance AIR QUALITY how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	◯	◯	◯	◯	◯
Technical equipment	◯	◯	◯	◯	◯
Infrastructure architectural design	◯	◯	◯	◯	◯

Please feel free to add a comment.

17. When evaluating architectural design strategies to minimise CARBON EMISSIONS and enhance AIR QUALITY how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Design airside layout to minimise aircraft emissions	◯	◯	◯	◯	◯
Reduce parking footprint	◯	◯	◯	◯	◯
Develop infrastructure to increase public transport	◯	◯	◯	◯	◯
Design and upgrade infrastructure and buildings to minimise carbon emissions (e.g. reducing the use of energy)	◯	◯	◯	◯	◯

Please feel free to add a comment and illustrate which architectural design strategies are you using.

18. When evaluating strategies to minimise or eliminate WATER POLLUTION how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	◯	◯	◯	◯	◯
Technical equipment	◯	◯	◯	◯	◯
Infrastructure architectural design	◯	◯	◯	◯	◯

Please feel free to add a comment.

19. When evaluating architectural design strategies to minimise or eliminate WATER POLLUTION how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Design to reduce stormwater quantity (e.g. reduce impervious areas, provide drainage infrastructure)	◯	◯	◯	◯	◯
Design to improve stormwater quality (e.g. provide water treatment systems)	◯	◯	◯	◯	◯

Please feel free to add a comment and illustrate which architectural design strategies are you using.

14

GrADE survey - The role of architecture in airport sustainability

Part III
Airport environmental sustainability - Evaluating strategies for *Green Airport Design*

20. When evaluating strategies to minimise or eliminate impacts from ENERGY USE how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	○	○	○	○	○
Technical equipment	○	○	○	○	○
Infrastructure architectural design	○	○	○	○	○

Please feel free to add a comment.

21. When evaluating architectural design strategies to minimise or eliminate impacts from ENERGY USE how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Design and upgrade buildings to reduce energy consumption	○	○	○	○	○
Design and upgrade infrastructure to reduce overall airport energy consumption	○	○	○	○	○
Use alternative and renewable energy sources	○	○	○	○	○

Please feel free to add a comment and illustrate which architectural design strategies are you using.

15

22. When evaluating strategies to minimise or eliminate impacts from WATER USE how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	○	○	○	○	○
Technical equipment	○	○	○	○	○
Infrastructure architectural design	○	○	○	○	○

Please feel free to add a comment.

23. When evaluating architectural design strategies to minimise or eliminate impacts from WATER USE how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Landscape and design to reduce water use (e.g. irrigation)	○	○	○	○	○
Design for water efficient use (e.g. employ water saving devices and/or waterless operating systems)	○	○	○	○	○
Design to maximize water harvest, recycle and reuse	○	○	○	○	○

Please feel free to add a comment and illustrate which architectural design strategies are you using.

16

24. When evaluating strategies to minimise or eliminate impacts from WASTE GENERATION (e.g. derived from airport activities and operations, infrastructure construction materials) how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	○	○	○	○	○
Technical equipment	○	○	○	○	○
Infrastructure architectural design	○	○	○	○	○

Please feel free to add a comment.

25. When evaluating architectural design strategies to minimise or eliminate impacts from WASTE GENERATION how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Design to provide storage and collection of recyclables	○	○	○	○	○
Design for deconstruction, reuse and recycling (e.g. design structures with modular, reusable, and de-constructible components)	○	○	○	○	○
Select recycled, bio-based and rapidly renewable materials	○	○	○	○	○
Select materials with high design service life, minimising maintenance and replacement cycles	○	○	○	○	○

Please feel free to add a comment and illustrate which architectural design strategies are you using.

17

26. When evaluating strategies to minimise or eliminate impacts on BIODIVERSITY and the HABITAT how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Operations management	◯	◯	◯	◯	◯
Technical equipment	◯	◯	◯	◯	◯
Infrastructure architectural design	◯	◯	◯	◯	◯

Please feel free to add a comment.

27. When evaluating architectural design strategies to minimise or eliminate impacts on BIODIVERSITY and the HABITAT how important are the following?

For each issue please select a number between 1 and 5 where 1 means that it is not important and 5 means that it is very important.

	1	2	3	4	5
Design the layout of infrastructure to avoid destruction of sensitive habitats	◯	◯	◯	◯	◯
Design infrastructure and buildings not to be attractive to some animal species	◯	◯	◯	◯	◯
Landscape and design to minimise land use and reduce heat island effect	◯	◯	◯	◯	◯
Design and technologies to reduce light pollution	◯	◯	◯	◯	◯

Please feel free to add a comment and illustrate which architectural design strategies are you using.

GrADE survey - The role of architecture in airport sustainability

Thank you!

Thank you for completing the survey. Your response will be useful to the*GrADE* research.

28. Are you available for a follow-up interview via skype or phone?

A follow-up interview to this survey may be useful to have additional details on some of your answers.

(If Yes, you will be contacted by the e-mail address you provided)

◯ Yes

◯ No

Please feel free to add any comment.

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The research is focused on the evaluation process of airport 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 since the early stage of project development.
Airports can be constrained by environmental issues which restrict current operations and limit future potential 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 demand a systemic approach to meet the need for change through better definition of the design process and compliance with green building requirements.
The research defined specific method and tools enabling both design project control and sustainability appraisal. The method is based on systematic process, linked to the development of sustainability indicators that would inform a site-wide approach to the design of airport infrastructure. GrADE method and 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.

La ricerca si inserisce nell'ambito di indagine e analisi delle problematiche relative alla gestione del processo progettuale per la sostenibilità. La ricerca si propone di sviluppare metodi e strumenti per la definizione delle prestazioni e delle strategie tecnologiche e progettuali relative alla valutazione della sostenibilità ambientale.
Lo studio è volto in prima istanza ad indagare le problematiche ambientali che emergono dallo sviluppo ed operatività delle infrastrutture aeroportuali. Tali problematiche riguardano il rumore, la qualità dell'aria, le emissioni di carbonio e gas serra, l'uso di risorse (energia e acqua), la produzione di rifiuti e l'utilizzo dei materiali, l'inquinamento delle acque, l'utilizzo del suolo e la salvaguardia degli habitat.
La ricerca ha delineato i contenuti degli strumenti per la gestione dello sviluppo progettuale del 'green airport design' e la valutazione delle scelte progettuali atte al soddisfacimento dei requisiti di sostenibilità ambientale nell'ambito della progettazione aeroportuale. Il modello proposto contiene schede specifiche per l'organizzazione dei parametri a supporto dei processi di decisione necessari sin dalle prime fasi del processo progettuale.

Paolina Ferrulli studied Architecture at the Università degli Studi di Firenze where she graduated with honours (2012) with a thesis in Architectural Technology and Project Design Management.
Teaching assistant (2012-2015) in the courses of Project Design Management and Environmental Design of the Dipartimento di Architettura at the Università degli Studi di Firenze. Within these courses Paolina had experience as lecturer addressing topics regarding airport environmental sustainability and green building assessment tools.
She has been a PhD visiting student (2014) at the Centre for Aviation, Transport and the Environment at the School of Science and the Environment at the Manchester Metropolitan University, where she worked under the supervision of professor Callum Thomas. During this internship she launched the *Architectural Concepts of Airport Sustainability* workshop that opened a cross-disciplinary dialogue between environmental scientists and architects on issues related to airport sustainability.

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