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"The 2050+ Airport"

Collaborative Project
Small or medium-scale focused research project

Area 7.1.6.2. – Step changes in air transportation operation
AAT.2011.6.2-3.Airports

# D4-3 The Cost-Effective Airport Concept

## An operational concept for 2050 and beyond

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## Executive Summary

The goal of this document is to provide a clear overview about the Cost-Effective Airport Concept.

According to ‘FlightPath 2050’ published by the European Union, “In 2050, the European air transport system is integrated in a complete logistical transport chain and part of a fully interconnected, global aviation system”. Especially within Europe, the aviation system will operate in an environment where other transportation modes, for example high-speed trains, will be much more effective than today. Therefore, to become more favourable than other transportation modes, the air transportation sector needs to be prosperous. This can be achieved by offering reasonable services at competitive prices, while maintaining the level of comfort and security.

The aim of the Cost-Effective concept is to provide an airport concept that makes the airport more cost-effective by reducing direct and indirect operating costs and by considering, at the same time, the potential for revenue increase. The net result of operating costs and revenues should be able to at least compensate for any future increase in investment costs.

This document focuses on two types of airports: green-field airports, which will be newly developed in the future, and existing airports. The cost-effective solutions proposed are therefore subdivided into those relevant to newly constructed airports, and those relevant to airports that already have important infrastructure in place.

In terms of layout/structure it is foreseen that by 2050 surface transport to and from the airport will be much quicker, more efficient and more predictable. In addition, security processes will probably consume less time than nowadays. As a result, the future airport terminal might change a lot. The current airside part of the terminal might evolve into a much smaller, minimised terminal. On the other hand, the current landside part of the terminal may evolve into a transport node which is not necessarily located at the airport but could instead be located within the city. This landside part of the terminal could become part of a railway station, providing security and boarding services and a fast, direct train service to the actual flights.

Although people will spend less time at such a city terminal airport, this loss in (e.g. shopping, parking) revenues may well be compensated for by providing extra services at the transport node/service centres or at the airport trains which could be partly owned by the airport. The “terminal in the city” and the “lean terminal” concepts support this direction. In addition, given the fact that airport terminals are one of the biggest cost centres for airports today, an important reduction of overall costs can be achieved by moving the landside part of the terminal towards city centres/railway stations. The required infrastructure and service centres can be shared with other transport modes, increasing the revenue/cost ratio.

In addition, automation of processes at airports will also have a strong impact on the costs and revenues of airports. Automation of services is already well underway at many of the larger European

airports today: e.g. the introduction of self-check-in and self-boarding equipment already paves the way to a seamless transportation chain in which the airport acts as a transportation node providing instant access to air travel. With the application of new services, solutions and technologies the airport terminal will become a transportation node providing easy access to travel similar to all other transport modes.

The cost-effective concept solutions proposed in this document may affect the airport services, the terminal layout and infrastructure, the airport airside infrastructure, and the turnaround processes. All solutions are aimed to procure a positive impact on the cost and revenue structure of the future airport.

Although radical new solutions typically imply an investment cost at the beginning, the aim is to significantly reduce operational costs in the long run. In this respect, solutions that improve the time-efficiency of the airport often also have a positive impact on costs – time is money. This impact can either be direct, when time-efficiency leads to a reduction in staff, or indirect, when revenues increase due to lower prices and/or better services attracting more passengers.

For the cost-effective solutions proposed in this document, the balance between the initial investment costs on the one hand, and the expected reduction in operational costs and increased revenues on the other hand, is expected to be positive or very positive. To support this statement, the impact of each concept solution on both non-aeronautical and aeronautical costs and revenues has been assessed by means of expert judgement during the second AP2050+ validation workshop. As a result, a list of best concept solutions has been extracted to support the cost-effective airport of 2050+. Selected solutions are ranging from state-of-the-art now, even if likely not implemented European-wide yet, to radical but not yet achievable solutions. An overview of the best Cost-Effective solutions can be found in section 6.4.1 of this document.

These solutions can be regarded as building blocks for the Ultra-Green airport of 2050+. The modular approach taken implies that not all ideas should be regarded as mandatory for a sustainable airport; instead, interested airport managers and stakeholders are given the choice to combine only those ideas that fit their specific airport, business plans, target groups and local community. Together with the Time-Efficient and Ultra-Green concept ideas, these solutions may offer the benefits to enable small, medium and large airports in Europe to become seamlessly integrated as nodes in the European Transport Network. With the development of these solutions and overarching concepts, the AP2050+ consortium hopes to contribute to the long-term development of European airports meeting the challenges of the far future.

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# 1 Introduction

## 1.1 Purpose of the document

The 2050+ Airport project develops three airport concepts for the future of 2050 and beyond. These three airport concepts are the Time-Efficient (TE), Ultra-Green (UG) airport concept, and Cost-Effective (CE) airport concepts. The Concept Development Methodology (CDM) of WP2 provides the guidance to the development of each of these concepts.

The purpose of this document is to report on the development process and the final outcomes of the CE airport concept. It outlines why the concept is developed, the requirements, the goals it intends to achieve, and how existing and expected bottlenecks and challenges in current airport operations are proposed to be adapted, to achieve time-efficient operations for the year 2050 and beyond.

## 1.2 Intended Audience

The intended audience is:

- The EU-Commission (European Union), DG Research (Directorate General), which commissioned the 2050+ Airport Project and which will assess project results;
- All European airports, the main stakeholders, which receive an operational concept that is intended to give guidance to the planning and decision making involved in developing towards the future;
- All other stakeholders (e.g. airlines, ANSPs (Aeronautical Navigation Service Provider), industry, passengers) with an interest in long-term development of the air transport system; and
- The 2050+ Airport consortium partners who will use the document to perform a high-level validation and give directions for further research.

## 1.3 Document structure

The purpose and background of the Airport 2050+ concepts is explained in Chapter 1. Chapter 2 discusses shortly the CDM, the methodology that has been used for development of the airport concepts [23]. Then, based on the Vision 2050 [4] and other relevant documentation that approaches the future airport related developments, Chapter 3 describes a more specific vision from a time-efficiency point-of-view, dealing with Key Focus Areas (KFAs), stakeholder interests, boundary conditions, and (operational and user) requirements. From this initial analysis, a value and objective structure is derived, focussing the CE concept development on key value-adding aspects. Chapter 4 describes a baseline airport, based on a high level decomposition of current generic airport processes and infrastructure. This reference allows the identification of today's most common critical elements, challenges and bottlenecks to the CE concept and where to improve operations. Chapter 5 describes the proposed advanced operational concept of the CE airport for 2050, including the several solutions which drive this concept. In Chapter 6 an appraisal of the impact of these changing operational conditions is conducted. Using the previously identified value framework, the expected benefits of the

CE concept's solutions are quantified in an industry experts involved workshop to distil the most promising ideas and combination of ideas. Finally, Chapter 7 offers conclusions and recommendations with respect to the CE airport concept and its development.

## 1.4 Background and context

The 2050+ Airport project is commissioned by the European Commission, DG Research, in order to study the perspective of far-future development of airports in Europe. The project explores new airport concepts with novel solutions, to support the development of airports of 2050 and beyond.

The project develops three different airport concepts. These three concepts address time-efficiency, cost effectiveness, and sustainability, with each airport concept strongly focusing on its own objectives. This means, amongst others, reduce the turnaround time of aircraft, reduce the throughput time for passenger from door to door, decrease airport's cost, increase airport revenues, minimise the airport's environmental impact, and strive for sustainability. Even if these aims are over-ambitious target values, they represent where the present concept of airports' deployment is most weak. The three concepts show what the future airport could look like and which level of performance can be expected. They describe the interface between aircraft and ground, passenger/baggage related processes, new airport operations management principles and how the application of new principles of airport layout can better integrate future intermodal connections.

More precisely, the project's main activities comprise:

- **Building a methodology for airport concept development (WP2):** A uniform methodology is established to develop the three different airport concepts. The methodology is based on value theory [4, 7]. It assesses the different stakeholder relations and interests, and provides a high-level set of objectives and attributes to set the focus of each concept. This makes it possible to rate the concepts' designs and make trade-offs between different proposed solutions.
- **Delivery of three concepts, one of which is the CE airport (WP4):** Several ideas will be captured mainly through workshops and brainstorming sessions. This in turn will create an initial version of the concepts in accordance with the methodology, which will be further refined by validation activities. The concepts will be updated and the process will continue following a spiral life cycle until they are considered sufficiently mature (i.e. European Operational Concept Validation Methodology (E-OCVM) late V0, close to V1 [6, 10]).
- **Partial validation of these concepts (WP3, [15]):** Validation activities will increase the maturity level of the concepts and enable performance assessments to be done. During the first cycle, the validation activities assess the feasibility of each solution. Based on this validation a first selection of most promising solutions can be made. During a second cycle any issues detected during validation will be used for further concept refinement and specification. This task ensures the coherence of the maturity level achieved by each concept. This report describes the current status of the CE concept and serves as input for the second validation cycle.

## 1.5 Why develop an airport concept for 2050 Europe?

The world is changing and towards 2050 a strong increase of air traffic demand is expected due to increase of population and consumption worldwide, as well as a strongly growing economy in the emerging markets. Also, the air traffic demand in Europe is expected to grow, but this has to happen under constraining conditions of accommodating growing traffic in limited space available around the airports and tight time provisions on for example taxiing, emplacement, and turnaround time.

The increase in European air travel demand is a result of the growing desire and ability of people within and outside of Europe to travel. This increased demand can only be accommodated if the European air transport industry is able to meet its targets to significantly enhance mobility, cost-efficiency and sustainability for door-to-door travelling. The Flightpath 2050 report sets the objective to allow 90% of European travellers to be able to complete their intra-European door-to-door journey within four hours. Europe will only meet this objective if the European Transport Network improves significantly, meaning that:

- The connectivity between the critical nodes (hubs) of the Air Transport network has to improve
- The connectivity between the Air Transport Network and other modes of transportation has to improve
- The network of nodes has to expand to offer full coverage
- A seamless service provision has to improve door-to-door travel time and meet the requirements for user-friendliness, sustainability and undisturbed service provision

This justifies the development of advanced airport concepts, reflecting the need to improve the airport's performance as the critical nodes in the European Transport Network. In a competitive world, constrained by several limitations, European airports have to develop to enhance their operations, strengthening their role in the network:

- Airports have to improve seamless connectivity between airports and door-to-door connectivity by providing enhanced connectivity services for their customers in their catchment area. This justifies the development of a TE airport concept for 2050, improving seamless operations and removing delays and other hurdles in travelling whenever possible.
- Airports have to reduce their costs providing seamless connectivity services in a competitive world. This justifies the development of a Cost-Effective (CE) airport concept for 2050, reducing costs and improving efficiency whenever possible.
- Air Transport has to reduce its impact on the environment by reducing environmental pollution and by reducing any possible waste in consumption of resources. This justifies a Ultra-Green (UG) airport concept for 2050, reducing the load on the environment as much as possible. This relates to all operations at and around the airport, comprising transport services as well as all other activities to build, maintain and operate the airport.

In order to be beneficial to airport development, the three 2050 airport concepts of the 2050+ Airport project are complementary to one another. The airport concepts aim to provide the airports as main stakeholders with new views and new ways to initiate implementation plans to meet the demands of the far future. The concepts are constructed by analysing a baseline reference airport and identifying processes, operations or infrastructural bottlenecks that can be significantly improved - each time with its specific focus on ultra-green, time-efficient or cost-effective improvements. (See the Definition of the Cost-Effective concept in the red box). Airports may ultimately choose their own specific solutions from each concept, benefiting from what suits their purpose and their vision to improve their competitive position within the European Transport Network.

***Definition of the concept of the Cost-Effective airport:***

*The Cost-effective airport is the airport that has been designed and is operated and managed such that the direct and indirect operating costs are minimized whilst keeping revenues as high as possible. In addition, the investment costs for new infrastructure (either for expansion or for newly developed airports) is minimized as well.*

# 2 Summary of the concept development methodology

This chapter summarises the Concept Development Methodology (CDM), which is used to develop the Cost-effective (CE) airport concept [8]. The methodology, as developed during WP2, essentially consists of four steps that should be followed: (1) describing the background of the concept, (2) analysis of a reference airport, (3) solution generation, and (4) initial value assessment. This chapter will describe these four steps in the subsequent sections and forms the base for the rest of the document.

## 2.1 Background of the concept: vision and objectives

The goal of the first step is to create a clear background on the development of the concept, how it is interpreted (definitions), what is in/out of scope and which requirements are derived. In this step the Vision 2050 [4] is re-examined to find which parts of it are key for the concept in terms of future forecasts, boundary conditions and pre-set performance goals.

Furthermore the Value Operations Methodology (VOM) [24] is applied, by setting down the value structure that will be used in the concept development. Working from the high-level value structure presented in the VOM framework, more detailed objectives and associated attributes are added to the value lever that is of primary focus (in this case time-efficiency). In this step also low-level weights can be assigned to all attributes. This part of the VOM has been applied in an early stage of the project, so a clear focus existed beforehand on what the concept intends to achieve (based on the expected CE needs of 2050), and which attributes are needed to measure this. Such focus will help direct the effort in the context analysis and solution finding phase.

## 2.2 Reference airport

When the concept's background, goals, and objectives are clear, an analysis of the current airport operational context is conducted. To make the final concept as widely applicable as possible, a generic, large hub airport is chosen and described in terms of processes, infrastructure, and/or services as the baseline situation (or 'reference').

After this, the baseline airport is analysed in detail using the tools and method presented in the first part of the Context and Architecture Description (CAD) method [24]. This analysis will point out where the key bottlenecks or challenges currently exist in airport operations and is concept-specific, i.e. what aspects in current airports are already main challenges that need to be overcome to achieve time-efficiency levels as derived from the concept background?

Finally, taking the found bottlenecks as a starting point, these are translated to a 2050 situation. What will it mean if current bottlenecks are not solved? Also, are there problems to be expected from other airport areas that are currently not a challenge for the concept, but will become so if no changes are made from now to 2050? This step distils those challenges that absolutely should be solved by the concept in light of the 2050 goals, as derived from the first step of the methodology (background).

## 2.3 Solutions and advanced airport concept

The foregoing analyses will have created a clear argumentation for the goals to be met by the Cost-Effective airport concept, and the aspects of current airport operations that need to be radically improved to achieve these goals. Using creative tools such as morphological analysis, design-option trees, brainstorming or any other means presented in the second part of the Context and Architecture Description [24], the innovative solution(s) (directions) to the 2050 challenges are now developed. This is the creative phase of concept development, guided by the findings of the previous two steps.

Solutions will be developed for specific airport areas (landside, airside, intermodal links – or a combination/integration of those if deemed worthwhile), together with an outline of their expected benefits to 2050 goals. It should be noted that some solutions can have impact on more than one process. Also, some solutions can be incompatible. This leads to a CE concept of airport operations, consisting of a number of selected solutions for 2050 and their expected benefits.

## 2.4 Change-Impact and Value assessment

Following the steps outlined in the Change-Impact (C-I) methodology [4], the changes constituted by the concept solutions are mapped to concrete operational processes/services/infrastructure. The information obtained from the context analysis provides the framework for this. The specific operational metrics attributes which are expected to be affected are also listed.

Then, using the quantification scheme outlined in the C-I method, the different impacts expected from these changes are estimated. This is initially done by the consortium partners (as shown in Chapter 5), but subsequently the input of the various airport operational and industry experts present at the second validation workshop of WP3 has been used to assess the impact of the proposed solutions on the value attributes (see Chapter 6). Specifically, the expert's C-I analyses will be used as input for the Value Operations Methodology and value structures, which in turn are used to calculate the value contribution (i.e. the $\Delta V$ score) for each solution. Apart from the C-I method, an expert judgment gaming session is used to provide an alternative way of evaluating the several concept's ideas. Both methods aim to determine the most promising Cost-Effective solutions/concept ideas and are further detailed in Chapter 6.

The results of the four steps of the CDM as discussed in this chapter will be elaborated in Chapters 3-6 respectively.

# 3 Background of the concept

The first step of the methodology is to understand the concept to be described and then to formulate a vision on 2050. From there the concept-specific objectives can be derived. An overall Vision 2050 was presented as part of WP2 of the AP2050 project in [4]. In this chapter, this vision is expanded towards a set of requirements for developing the Cost-Effective (CE) airport of 2050. To this end, first the scope of the Cost-Effective airport concept is discussed in section 3.1. Next, each Key Focus Area and the stakeholder interests are assessed in section 3.2. Section 3.3 uses this 'expanded' vision to derive requirements/objectives specific to the CE airport concept. The outcome, in terms of scope, context and objectives, is summarised and concluded in section 3.4.

## 3.1 Understanding the CE concept

The goal of this concept is to introduce an airport which operates at the minimum possible cost whilst keeping revenues as high as possible and maintain, if not improve the level of safety and security.

The concept focuses on future changes of the airport with regard to real estate and associated services, the apron, including aircraft handling activities. The intermodal connections are not elaborated specifically; however, it is supposed that the terminal building should support seamless intermodal access. The concept does not detail ATM procedures as such (out of scope). Nevertheless, an overview is given about future ATM developments that may influence the service structure of the future.

The CE concept assumes that future airports will be operated in an environmentally sustainable manner. This means that an automated recycling system will handle waste and sewage, the buildings will be active (or at least passive) producing their own energy needs by themselves and environmental-friendly materials will be used, etc. The CE concept is thus built on the hypothesis that, due to a foreseeable increase of environment-related taxes and fees, a future cost-effective airport should be sustainable as well to avoid extensive unproductive costs emerging from fees of this nature. The level of sustainability of the cost-effective airport of the future should be in line with the level of environmental standards. The reason for this is that green solutions are more and more supported by the governments and this can be expected to be valid for the future as well.

### 3.1.1 Conceptual definitions and the scope of operations

The CE concept of the 2050 Airport addresses daily operational challenges, in first instance. Airports, however, are not only concerned with daily operations: design, development, and constructions are considered very important as well. The CE concept therefore addresses not only operational challenges, but also partly the Cost-Effective challenges in the area of design, development, and constructions. The Concept Development Methodology (CDM) describes what is inside and what is outside the scope of airport concept development within the AP2050+ project. For example, flight operations, and in particular departure and arrival procedures are out of scope since part of ATM, whilst platform operations and therefore also the related part of aircraft design are within scope. New aircraft design may have an impact on airport design, airport operations and airport deployment, and can therefore be an essential part of the concept as such.

In the definition of the airport concept, the Cost-Effective airport concept assumes operations by aircraft types optimised towards cost-effective service provision. This definition of an extended scope of operations is necessary in order to be able to describe a credible and in itself consistent scope of operations of an airport concept. Not only the airport itself is assumed to optimise its operations towards Cost-Effectiveness, but also the world around it and its operations have to be aligned with the main theme of the airport concept.

### 3.1.2 Definition of an airport within the project

In the context of this project, the airport is understood as the geographical territory of the airport including:

1. A tract of levelled land where aircraft can take off and land, equipped with one or two hard-surfaced landing strips, a control tower, hangars, aircraft maintenance and refuelling facilities, and accommodations for passengers and cargo.
2. Areas dedicated to facilitate all other movements required to use airport services, i.e. all facilities to reach the airport by means of public transport, i.e. by trains, underground, buses and shuttles, and all areas dedicated to facilitate private transport, to access the airport by car.
3. Areas for industrial activities, hotels and community activities, related to the success of the airport, but not belonging to deployment of the airport as such, but supporting it to be able to act as an intermodal node in the transport network.

The airport is the start-, transfer-, and end-point of air travel and its scope of operations is essentially linked to its terrain limits. Flight operations are also out of the scope of the concept. Further details of the airport scope are outlined in D2-1-2 of the WP2 methodology [24].

## 3.2 Global trends, key focus areas, and scope of operations

The vision document [4] a global view of the world in 2050. This vision document does not aim to accurately predict the future, nor does it aim to cover all possible scenarios for year 2050. Instead, the vision considers a group of specific key focus areas - Demography, Society, Politics, Economics, Environment, Mobility and Technology - and suggests how these areas should be taken into account by the airport of 2050+.

In addition, the vision document describes the interfaces between airport and aircraft and between passengers, the baggage and airport. The vision document introduces the idea of stakeholder groups having similar interests/expectations. Below the relevant Vision 2050 aspects for the CE airport are summarized.

Table 1: Relevant Vision 2050 aspects for the CE airport, source: [4]

| KEY FOCUS AREA | ASPECTS AFFECTING CE CONCEPT | VALUE CONSIDERED |
|---|---|---|
| **Demography** | • Growing of world population.<br>• Pollution and noise effects.<br>• Needs of an older society. | • 9 billion (+28.6% from 2011)<br>• EU: 500 million (constant from 2011)<br>• 30% of population will be over 60 years (+5% compared to 2010) |
| **Society** | • Evolution of a global middle class.<br>• The 2050 world will likely be based on connection.<br>• Society of 2050 will also be quite environmentally aware.<br>• 2050 society as a whole will have stronger influence and impact. | • % of population travelling by air transport<br>• Use of Information and Communications Technologies (ICT)<br>• Leisure travel: 70-80% of air travel by 2050 |
| **Mobility** | • Operations:<br>• Door-to-door service<br>• The entire transport chain will need to be robust.<br>• The air transport system will need to be optimized as a whole.<br>• The operational and control systems should be much more flexible<br>• Safety and Security:<br>• People will demand ever-increasing safety and security.<br>• New conflicts can increase the threat of terrorism.<br>• In the demand for smooth travel, people want to have the least amount of hassle from e.g. security measures<br>• Security focus will remain high, but more realistic: focusing on efficiency, objective threats and invasive only if strictly needed.<br>• Increases in automation will make it paramount to assure high levels of reliability and thus safety in all situations. | • % of operations<br>• % of passenger on connection<br>• Increase of security checks<br>• Worldwide traffic growth 4-5% per year<br>• Worldwide RPK growth 2.5-3.5% per year between 2000-2050<br>• Worldwide air travel passengers 16 billion per year (+ 540% from 2011)<br>• Commercial EU flights<br>• 25 million per year (+ 166% from 2011)<br>• European air travel passengers<br>• ± 3-4 billion [+300-430% from 2009]<br>• Needed airport capacity increase<br>• >70% from 2005-2050<br>• Door-to-door EU travel time<br>• 90 % <4 hours<br>• Schedule deviation<br>• 99% within ±15 min<br>• Airport operating hours<br>• 24 hours operations of airports possible<br>• Time spent by passengers in airport related processes<br>• <15 min. (short-haul); <30 min. (long-haul) |
| **Technology** | • Current aero-engines optimized to maximum fuel efficiency.<br>• Kerosene still used at a highly | • SESAR has been successful. New technologies (A-SMGCS) are implemented at most large airports. |

| KEY FOCUS AREA | ASPECTS AFFECTING CE CONCEPT | VALUE CONSIDERED |
|---|---|---|
| | costly level, but complementation by biofuels is much more prevalent.<br>• Increased use of non-oil technologies such as solar, hydrogen and perhaps even nuclear power for non-aeronautical power.<br>• SESAR will be fully implemented.<br>• Increased capability for safety/security-checks.<br>• Increased use of automated machines.<br>• Optimized aircraft designs. | Data communication (largely) replaced voice R/T. R/T existing only as backup<br>• The ATM network is able to cope with the demand. This means that the system is able to process all traffic and offer it to the aerodromes. As such, research can focus on airport bottlenecks.<br>• Complete integration of airport operations in the aircraft trajectory possible (e.g. SWIM) |
| **Economics** | • Positive growth rates are most likely in the long term.<br>• The current crisis may lead to stricter economic regulation, limiting access to funds to development programmes and investments by airports/airlines. Any new technology will have to demonstrate clear economics feasibility on shorter terms.<br>• New economic powers (Asia, Brazil etc.) will emerge, tough competition is expected.<br>• Scarcity of oil will drive up fuel cost to a very large percentage of operating cost (up to and over 50%). This will drive the need for alternative and sustainable fuel sources.<br>• Increased demand at lower prices will create severe cost pressures for operators | • Global economic growth rate: ± 3% per year<br>• GDP growth for Europe: 1.7 % per year from 2005-2050<br>• Average EU per capita growth: ± 1.5-2.0% per year from 2010-2050 |

Regarding the stakeholders, the vision document proposes a detailed classification of stakeholders. For the CE concept, the following stakeholders and their interests are of particular importance, as shown in Table 2.

Table 2: Stakeholders relevant for airport cost-efficiency with their interests, source: [4]

| **No. (in Vision Doc.)** | **Stakeholder** | **Interest / behaviour** |
|---|---|---|
| 05 | Airports | • Want to make profit<br>• Want to serve all demand for air transport<br>• Want to be as efficient as possible (time, cost, sustainability) |
| 06 | Airlines | • Want to make profit<br>• Want to serve all demand for air transport<br>• Want to be as efficient as possible (time, cost, sustainability) |
| 09 | Users | Origin/Destination passengers<br>• Want very quick and seamless access to mobility (i.e. this does not have to be an aircraft, just what is most efficient in terms of cost, time)<br>• Pragmatic to travelling/connection: road, rail, air, e/ICT<br>• Open to/preferring sustainable air transport / mobility<br>• Wants cheap air transport<br>• Want to stay connected all the time<br>Transfer pax<br>• Want efficient, fast connection (no waiting)<br>• Want to stay connected all the time<br>• Want cheap air transport<br>• Open to/preferring sustainable air transport / mobility<br>Freight transporters<br>• Want to have cheap prices<br>• Want quick and efficient transport<br>• Want seamless connection to road/rail/water |

The stakeholders are limited to these three because they are more affected in terms of airport cost-efficiency in the following ways:

- In the short term, the interests of **Airports** and **Airlines** are mostly directed towards profitability. These stakeholders are also open for improvements in time-efficiency if improvements can be translated into quantitative figures yielding cost savings or revenue growth. Finally, they are likely to give long-term sustainability the lowest priority, behind the need to assure their short- and mid-term survival.
- **Passengers** are also sensitive about prices, although this sensitivity should be balanced with their demand for time-efficiency – with important differences between leisure and business travellers. The introduction of low-cost airlines successfully ruined the “premium” image of air travel, the factor that conventional carriers relied on from the beginning. This drives conventional carriers into a tough competition. **Freight transporters** on the other hand are also in competition, where time and cost-efficiency are strongly related: quick forwarding of goods costs more, and vice versa.

## 3.3 Detailed objective structure

The high level objective structure introduced here is originating from D2-1-2 Methodology framework [23] and introduction of the Value Operations Methodology [24] document:

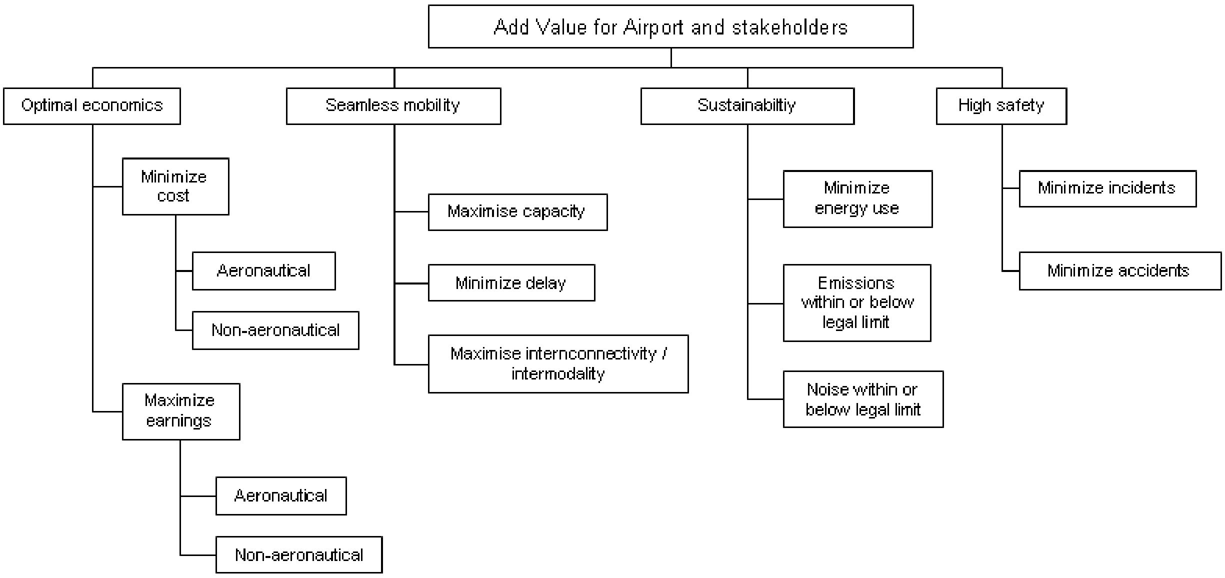



Figure 1: High level value structure

This objective structure aims to define the objectives to be met by all three concepts including safety and forms the basis for assessment and quantification of the added value of specific concept solutions in WP3 (Validation) of the AP2050+ project. As can be verified from the above Figure, Cost-Effectiveness ('optimal economics') can be subdivided into a minimization of aeronautical and non-aeronautical costs, and aeronautical and non-aeronautical earning/revenues. These four main categories can be further subdivided into underlying objectives as detailed in the table below:

Table 3: List of cost and revenue categories

| | AERONAUTICAL | NON-AERONAUTICAL |
|---|---|---|
| Costs | Usage of land (runway, taxiway, apron, ANSP)<br>Provision of navigation instruments<br>Marshalling services<br>De-icing (gates) equipment<br>Equipment for aircraft handling (if provided by airport)<br>Personnel services | Maintenance of terminal building<br>Equipment for passenger handling<br>Firefighting / police / medic capabilities<br>Rentals<br>Materials and supplies<br>Depreciation<br>Administration<br>Personnel services<br>Parking facilities |
| Revenues | Landing fee<br>Passenger charges<br>Parking fee<br>Freight charges<br>Apron services and aircraft handling (if | Rent or lease income<br>Recharges to tenants<br>Concession income<br>Direct sales<br>Car-park revenue |

| | **AERONAUTICAL** | **NON-AERONAUTICAL** |
|---|---|---|
| | provided by airport)<br>Fuel throughput surcharges<br>Passenger, freight and baggage handling<br>Noise and environmental surcharges<br>Ground Support Equipment (GSE)<br>Charges (defers per airport)<br>Air navigation fees | Non-airport related activities (e.g. land development)<br>Miscellaneous (e. g. interest earned)<br>Passenger fees<br>Security charges<br>Cargo facilities |

As a subsequent step towards elaborating the Cost-Effective objective structure consists in the assignment of attributes (cf. KPIs) to objectives, and the choice of a proper metric for quantification. The following table yields the attributes of the most important objectives distinguished above including a proposed metric.

Table 4: Cost-Effective objectives, attributes and metrics

| **AREA** | **OBJECTIVE** | **PROPOSED ATTRIBUTE** | **METRIC** |
|---|---|---|---|
| Economics | Minimize Aeronautical cost | Aeronautical cost | [€/WLU] |
| | | Usage of land (runway, taxiway, apron) | [€/WLU] |
| | | Provision of navigation instruments | [€/WLU] |
| | | Marshalling services | [€/WLU] |
| | | Remote de-icing (gates) equipment | [€/WLU] |
| | Minimize Non-aeronautical cost | Non-aeronautical cost | [€/pax] |
| | | Maintenance of terminal building | [€/pax] |
| | | Energy supply | [€/pax] |
| | | Rest rooms | [€/pax] |
| | | Security | [€/pax] |
| | | Cleaning | [€/pax] |
| | | Transport between terminal buildings (for PAX) | [€/pax] |
| | | Provision of firefighting capabilities | [€/WLU] |
| | Maximize Aeronautical income | Aeronautical revenues | [€/WLU] |
| | | Landing fee | [€/WLU] |
| | | Noise and environmental surcharges | [€/WLU] |
| | | Parking fee | [€/WLU] |
| | | Ground Support Equipment Charges (defers per airport) | [€/WLU] |
| | | Air navigation fees | [€/WLU] |
| | Maximize Non-aeronautical income | Non-aeronautical revenues | [€/pax] |
| | | Passenger fees | [€/pax] |
| | | Security charges | [€/pax] |
| | | Terminal rent for office space or other | [€/WLU] |
| | | Concession fees (for shopping, terminal catering, etc.) | [€/pax] |
| | | Cargo facilities | [€/WLU] |

| AREA | OBJECTIVE | PROPOSED ATTRIBUTE | | METRIC |
|---|---|---|---|---|
| | | | Catering facilities (on board) | [€/pax] |

For reasons of comparison, the tables below yield the objectives, attributes and metrics for the two other concepts in AP2050+: Time-Efficiency (mobility) and Ultra-Green (sustainability). In addition, objectives, attributes and metrics are suggested for safety, another important area of interest of airports that is however out of scope of the project.

Table 5: Division of Mobility weight factors

| AREA | OBJECTIVE | PROPOSED ATTRIBUTE | METRIC |
|---|---|---|---|
| Mobility | Maximise capacity | Annual pax capacity | [millions] |
| | | Maximum airside capacity | [moves / hr.] |
| | Minimize delay | Average delay level | [min.] |
| | Maximize intermodality | Average intermodal time | [min] |

Table 6: Division of Sustainability weight factors

| AREA | OBJECTIVE | PROPOSED ATTRIBUTE | METRIC |
|---|---|---|---|
| Sustainability | Keep Noise within or below legal limit | Total annual noise | [Lden, EPNdB] |
| | Minimize energy use | Energy consumed | [KWh/yr] or [GJ/yr] |
| | Minimize emissions | Airport NOx emissions | [kg/yr] |
| | | Airport CO2 emissions | [kg/yr] |

Table 7: Division of Safety weight factors

| AREA | OBJECTIVE | PROPOSED ATTRIBUTE | METRIC |
|---|---|---|---|
| Safety | Minimize incidents | Incidents probability | [#/106 flights] |
| | Minimize accidents | Accidents probability | [#/106 flights] |

## 3.4 Summary of Scope, Context and Objectives of the CE-airport Concept

The Cost-Efficient concept is developed against a scenario in which:

a) The achievable margin of revenues decreases significantly faster than the operating costs. Stakeholders (especially leisure passengers and freight-forwarders, but also business passengers as end-users of the transportation system) are extremely sensitive to the amount they pay for the services. This sensitivity can be initiated by an intensive competition generated by a decrease in demand as well as a significant change in world economics making common living expenses extremely high, amongst other reasons.

b) A cost boom is experienced, due to sudden raise of energy prices, labour costs, taxes, etc. Costs increase quicker than the maximum rate of tolerable price raising, and the only way for the air transportation to survive is a radical cost cut.

The self-explanatory performance indicator of cost-efficiency is the profit rate, that is, the difference between the revenues an airport can realize and the expenses it has to incur to achieve them. The aim is to "open the scissor" as much as possible – in other words, to maximize profits. Since it is quite likely that being sustainable and especially time-efficient will have - to a certain extent – a positive effect on cost-efficiency in the future, the two other concepts of the Airport2050+ project, the Time-Efficient and Ultra-Green airport concepts, will have targets and/or indicators at least partly overlapping with the Cost-Effective concept. Above tables 4, 5 and 6 show the key performance indicators for economy, mobility and sustainability domains.

# 4 Reference for the Cost-Effective airport concept

The CE concept seeks to find a solution to radically reduce operating costs of an airport, whilst keeping revenues as high as possible. Since airports are complex structures involving a large variety of processes, there is no single technological improvement to reduce all costs; a combination of solutions targeted towards the costliest airport processes should however have a significant positive impact both on overall costs and overall revenues. In this chapter, first a short introduction is given on the development of modern civil aviation, setting the background for further analysis (4.1). Next, a detailed desk research analysis of airport costs and revenues is carried out to define a reference cost and revenue structure for the CE airport of the future (4.2). Finally, a baseline airport description is given detailing the specific airport elements relevant to the Cost-Effective airport (4.3). Based on the reference airport described in this chapter, improvement ideas (alternatively called concept solutions) will be developed in Chapter 5 to reduce the highest costs and increase revenues.

## 4.1 A short history of contemporary aviation from 1970 until now

Despite the current economic/financial crisis, air transport has displayed a tendency of continuous growth for the last six decades, with no signs of decline in the near future. After the World War II many countries agreed on a need of similar rules and freedoms of the air for international aviation. As a result, the International Civil Aviation Organization (ICAO) [21] and the International Air Transport Association (IATA) [20] were both established in 1945. Both organizations are working towards the standardization of the aviation laws, in support of safe and reliable air services. The Airports Council International organization (ACI) [1] was established in 1948. The ACI aims to promote cooperation amongst airports, amongst other responsibilities. The establishment of these organizations led to the passenger jet era [8]. The 1960s experienced a boom in airport constructions. Since then, a close relation between growth of passenger and freight transportation volumes reflects a growth of the whole air transport sector as a fast and reliable mode of transport for both goods and people.

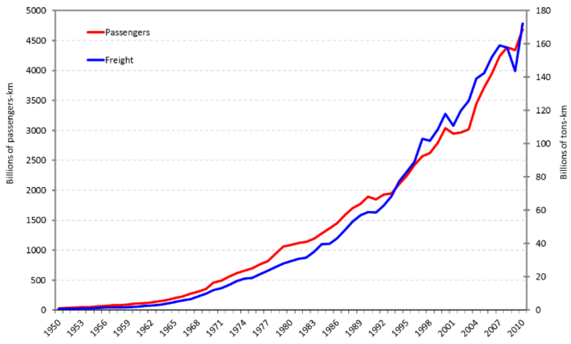



Figure 2: Number of passengers and freight, 1950-2010 [15]

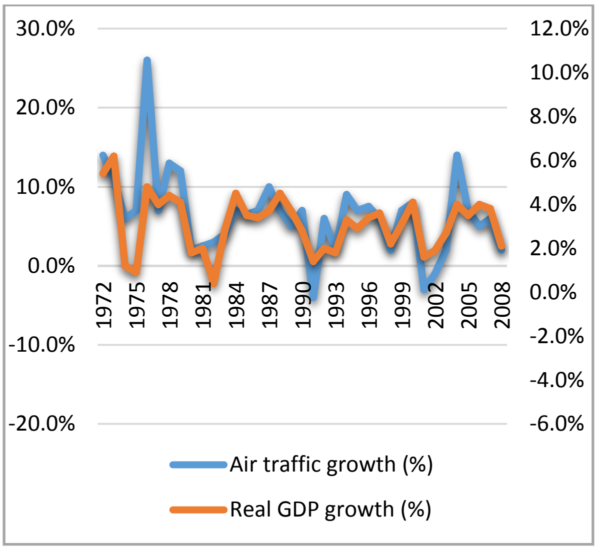



Figure 3: World air traffic growth correlation with world's GDP, 1972-2008 [15]

The main growth drivers of mobility and freight shipment are *economy and demography:*

- Decreases in world air transport sector performance are triggered by a global recession as air transport sector is highly dependent on the economic and political situation in the world and is closely linked with the world's GDP (see Figure 1). The growth of the world's GDP has a positive impact on the growth of the air transport sector: more passengers and goods need to be transported. If the economy is slowing down or falls in to recession, air transport freight and passenger volumes will decrease as well.
- The growth of demand for passenger air transport worldwide is sustained by demographic growth [12]. The world population is expected to grow and reach about 9 billion people in 2050 [12]. The highest population growth is expected in the developing countries (e.g. the BRIC countries: Brazil, Russia, Inda, and China) while Europe's population is expected to only grow with a moderate 12% by 2050. Developing countries, especially those in Asia, are expected to develop a huge demand for air transport, which will fuel air transport sector growth in the upcoming decades.

Passenger travel by any transport mode, and in particular by air, are forecasted to continue increasing in the future as a consequence of globalisation - tourism, regional integration and migration - which in turn will increase labour and business-related mobility, and associated social mobility (visiting relatives and friends). Moreover, rising incomes, ageing populations and lower transport costs will increase leisure travel [12]. According to a prognosis provided by ICAO and Airbus [3] (see Figure 4.3), air traffic is expected to double within next 15 years based on current development trends. The greatest share of air transport growth is expected to come from emerging economies, although the more advanced economies are expected to display a growing demand for air travel as well [12].

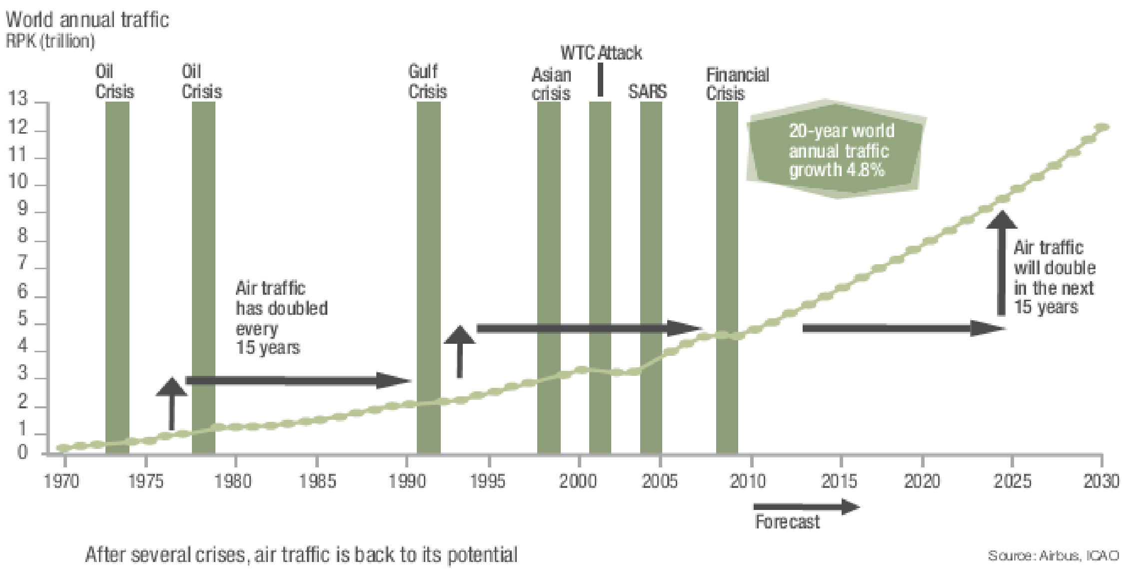



Figure 4: .Forecast for growth of air traffic [3]

As explained above, modern air transport sector is mostly affected by the demand – the numbers of passengers are continuously growing and further growth is expected. Any sector with increasing demand is attractive to business: privatisation of airports are more and more common practice. Privately owned airports may very well be managed more effectively than state-owned airport, as any other business seeking profit. Increasing and maintaining effectiveness requires adoption of modern technology. The table below aims to summarize the most important factors impacting air transport in the future.

Table 8: Factors influencing air transport development

| FACTOR | EFFECT |
|---|---|
| Increased number of passengers | Due to the expected larger number of passengers maximum capacity of large airports will be achieved and expansion of medium and small airports is expected to fulfil growing market needs. It will certainly influence the cost structure of the airports especially in terms of economies of scale because of bigger number of passengers. Considering the correlation between airport size (in terms of number of passengers) and airports staff costs as a significant proportion of whole costs it is possible that rate of staff costs could be restructured in the future. |
| Privatisation of airports | More and more European airports operators are privately owned or run as a public-private partnership. [1] The trend of privatisation process of airport sector could lead the European airport cost structure converge to the cost structure of U. S. airports by means of increased part of depreciation or capital costs because of changed depreciation and financing policy. |
| Technologic changes | Technologic changes are likely to have positive impact on personnel costs and negative impact on maintenance costs. Successful technology use would decrease the number of employees needed with the effect of smaller staff costs by transferring |

[1] http://www.airport-business.com/2010/07/aci-europe-launches-first-ownership-report-on-europes-airports

| FACTOR | EFFECT |
|---|---|
| | employees to assignments with better potential for direct profit (such as point-of-sales in the Transportation Centre, etc.) however increase of the maintenance costs due to larger numbers and more complex equipment is likely to follow. |
| Environmental regulations | Regulation reconciling the environmental, social and economic demands to address the growing global sustainability concerns [11] would affect expenses on environmentally friendly and social friendly aircraft technologies. Pressure of society and governments to increase efficiency of airport services will increase as well therefore maximum utilisation of resources will be necessary reflecting in operating costs. |
| Expansion of low cost carriers | The low cost carriers are pressing airports to reduce serving fees resulting in lower aeronautical revenues of airports. The increased number of types of commercial income is expected due to increased passenger flows and need to compensate losses of declining aeronautical revenues. |

All factors above are likely to have an impact on the cost and revenue structures of airports.

## 4.2 Reference cost and revenue structures

In order to develop ideas contributing to the CE goal of radical cost reductions with high revenues, a solid reference for current cost and revenue structures is required. To provide this reference, the cost and revenue structures of current-day airports have been analysed and is described in this section. The analysis provided a good insight into how airport services and service aspects contribute to costs and what operational activities should be focused on to achieve significant reduction costs and/or revenue advantages for the future airport of 2050+.

The contents of this section is based on extensive desk research (analytical work using publicly available statistics, articles, studies and other research papers). Secondary sources of information were necessary to provide an overview of the development of civil aviation sector in the world and Europe during the period of 1975-2012. This period was chosen for historical reasons, since civil aviation as we know it now started developing in late 70’s in United States of America when the air transport market was liberalised (see section 4.1 above). Before the 1970s, most major airlines were flag carriers, sponsored by their governments and heavily protected from competition. Liberalisation of air transport market lead to a strong increase in competition between airlines and airports, which in turn lead to a significant reduction of prices for travellers and an increase of the popularity of air transport.

A number of differences between American and European airports can however be identified: for instance, different traveller behaviour appeared in the last several decades, since the Americans had been travelling already between their states for a long time due to the absence of a number of restrictions. The Europeans, on the other hand, have only recently begun to move freely between European countries when the Schengen treaty was signed. Due to this difference in development, American airports were better adapted to the competition in the free market while European airports are still to catch up in certain respects, such as management models and investment policy.

For the reasons stated above, data was retrieved and examined for the period of 1975 until now. Further paragraphs are structured to overview the following specific periods:

- 1980-2000, early development period of civil aviation; this period was analysed to identify fundamental cost and revenue trends;
- 2000-2012, development period of modern aviation as it is now, to define current cost and income structures;
- and 2013-2050, for future forecast.

The periods 1980-2000 and 2000-2012 were chosen with an eye on the dramatic changes in airport operational activities after the September 11th attacks in the year of 2001. This unfortunate event revealed the vulnerability of air transport, resulting in drastic regulation and policy changes. These changes focused on increasing operational safety and security, creating additional costs as well as revenues. In addition, substantial changes in maintenance, operation and security costs occurred; a separate cost and revenue structure overview for each of the identified periods will provide more accurate analysis results.

### 4.2.1 Methodology for the analysis of airport cost and revenue structures

The costs structure case study central to the remainder of this chapter has been carried out by analysing and comparing the costs of different airports throughout the world. The data series of the costs of the researched airports were extracted from annual reports (see [1], [12], [3], [10], [22], [16], [7], [2]) and other airport-related sources (basically, desk research activity). Calculations for the analysis were carried out using data series extracted from secondary information sources during the desk research. The cost ranges for each year of the investigated periods were determined based on (1) past trends identified during the desk research, (2) assumptions and forecasts identified through desk research, and (3) expert judgement by the project team. An average airport cost structure was then defined based on the identified costs ranges. This cost structure was expressed as a percentage of the total costs airports face today. The outlined approach allowed the assessment of airport costs whilst eliminating foreign exchange differences and purchasing power differences.

The revenue structure case study was – analogous to the cost structure case study - carried out by analysing and comparing the costs of different airports throughout the world. The data series of the revenues of the researched airports were extracted from annual reports and other airport-related sources (basically, desk research activity, see [1], [12], [3], [10], [22], [16], [7], [2]). Calculations for the analysis were carried out using data series extracted from the secondary information sources during the desk research. In this analysis airport revenues are subdivided into aeronautical and non-aeronautical revenues. *Aeronautical revenues* indicate revenues that arise directly from aviation activities – operation and landing of aircraft, handling of passengers or freight. *Non-aeronautical revenues* are generated from commercial activities not related to the elementary air transport service provision itself.

During data research for both airport costs and revenues an important difficulty was encountered: there is no common, univocal system for individual airports to attribute airport costs or revenues to aeronautical or non-aeronautical costs or revenues. As there is no single standard on how to account costs and revenues, each airport may employ a different accounting methodology depending on country, management model, etc. If there is no standard accounting methodology, all accounting reports are unique, making benchmarking nearly impossible: one airport cannot be compared to another to evaluate effectiveness of investment, operations, management, strategy implementation, costs and revenues.

If a standardised accounting methodology would have been used, it would have been much easier to determine which airports would stand out during benchmarking activities; in addition, a best practice would be much easier to identify. Given the fact that there is no easy way to identify best-practice or effective airport operation improvements, the overall development of the air transport sector might be negatively affected.

### 4.2.2 Accounting methods for costs and revenues

In order to satisfy the rapidly growing yet highly competitive air traffic market, airports have however adopted different strategies. The costs of most of the airports consist of similar expenditures, since strict safety and aviation standards require airports to be equipped with standardised minimum equipment, to provide minimum standard security measures, to employ personnel to attend passengers, to implement security and safety measures for aircraft maintenance and fuelling equipment, etc. Despite the fact that cost structure elements of airports may show large differences due to different accounting practices, the following common cost elements are present at all airports:

- *Staff costs:* the number of staff depends on the hourly staff demand of a particular airport and is usually determined by the busiest peak hours. The demand for staff during morning or evening peaks might require additional part time shifts while during less busy hours smaller numbers of staff are necessary. If an airport is operating late hours or during the night, additional staff costs add up due to higher pay rates.
- *Depreciation costs* (or capital if interest payments are added). Airports are required to provide enough capacity to handle the demand which often entails the need for expansion or at least modernization of existing infrastructure. Investment in the development of the airport is usually accounted for through depreciation costs; therefore, reduced investment reduces the depreciation costs for the coming years;
- *Maintenance and repair costs*. Daily maintenance as well as repairs are unavoidable to ensure safety and continuous service provision. Some airports choose to outsource maintenance activities; the fees for this service provision still amount to a significant share of total costs though;
- *Security costs*. The costs for airport security rapidly increased during last decade after several incidents with passenger services caused by international conflicts. Security rules were

tightened, leading to an increase in costs due to purchases of new equipment and employing additional staff.

Apart from these common costs, many other costs can be distinguished. The actual cost categories employed depend – apart from the specific characteristics of the airport itself – on the specific accounting method employed by the airport. In general, a wide variety of accounting methods can be used to record airport costs and revenues for both internal (managerial) and external (financial reporting) purposes: (full) absorption costing, direct costing, marginal costing, variable costing, contribution costing, activity-based-costing, amongst others. Discussing these types of financial and/or internal management accounting methods[2] is clearly out of scope of this document; since the accounting method does however impact the types of costs distinguished at airports, this section briefly discusses two popular accounting methods: variable costing and absorption costing.

Absorption costing is a cost accounting method in which all fixed and variable costs are apportioned to so-called cost centres where they are accounted for using absorption rates. Absorption costing includes not just the costs of materials and labour, but also of all overheads (whether ‘fixed’ or ‘variable’).This method ensures that all incurred costs are recovered from the selling price of a good or service. The method is specifically suited for external reporting purposes: The Generally Accepted Accounting Principles (GAAP) require absorption costing for external reporting.

Variable Costing (alternatively called contribution costing, or direct costing), in contrast, is a cost accounting method that only takes overheads into account that are incurred *in the period that a product/service is produced/delivered*. This addresses the potential problem of absorption costing allowing management to push forward costs to the next period if products/services are not sold/delivered in the current period, leading to inflated profits in that period. Under variable costing, the cost of a product or service is determined by allocating to it an appropriate portion of only the *variable* costs, treating fixed costs (e.g. administrative overhead) as period costs (associated with time and not output). Variable costing is generally not used for external reporting purposes; it can however be an important aid to internal management decision making.

Key to absorption costing is the specification of cost centres to which all fixed and variable costs are apportioned to. Conversely, variable costing is typically much closer to the airport’s internal management accounting system and corresponding organizational structure. As a consequence, the costs are categorized and structured in a different manner than for absorption costing: more in line with the organizational structure and corresponding budget allocation of the airport. See the Table below yielding two example cost structures for a typical airport: one based on absorption costing, one on variable costing (taken from [9]).

[2] In general, a distinction is typically made between cost accounting, aimed to provide insight into costs/revenues for internal management decision making, and financial accounting, aimed to support financial reporting to external stakeholders (e.g. government, shareholders, investors etc.)

Table 9: Cost structure examples

| TYPICAL EXAMPLE OF COST STRUCTURE BY ABSORPTION COSTING [9] | TYPICAL EXAMPLE OF COST STRUCTURE BY VARIABLE COSTING [9] |
|---|---|
| Aircraft movement area | Direct personnel costs (staff) |
| Hangars and maintenance areas | Depreciation |
| Cargo terminal facilities | Debt service |
| Air traffic control and communications | Taxes |
| Meteorological services | Capital costs |
| Passenger terminal area (including gates) | Utilities and communication services |
| Ambulance services | Maintenance and repairs |
| Security services | Materials and supplies |
| Fire fighting | Rentals |
| Other facilities and services | Administration |
| Total | Other operating and non-operating costs |
| | Energy |
| | Total |

Note that the classification of costs by "cost centres" under absorption costing provides and gives insight into the costs generated by activity or object of the airport: e.g. the firefighting cost centre will include employee costs, equipment costs, supply costs, building maintenance, etc. This yields a good insight in the costs (and benefits/revenues) incurred by each activity required to produce the final service/product; on the downside, however, absorption costing is rather complex. For instance, many costs, such as energy costs, are shared between different costs centres and it may be very difficult to measure the exact use of energy of each cost centre object.

In contrast to absorption costing, variable costing doesn't follow the Generally Accepted Accounting Principles (GAAP). It depends on decisions of a particular airport regarding which areas to focus on and how to record the costs incurred. Cost classification typically groups together costs originating from different activities of the airport: e.g. staff costs, including all employees, disregarding the function of the employee (e.g. fire fighters and security staff will be accounted for in the same category).

Comparison of cost structures between airports should always take into account which accounting method is used. Even when comparing to airports that both use e.g. variable costing, however, a good comparison might be difficult. Different cost categories will likely apply, and even if similar titles are used, a large level of variation is possible given the freedom airports have to define their own cost categories. Absorption costing following GAAP in principle allows for less freedom, and thus better possibilities for comparison; nevertheless, the specific cost centres distinguished might be regarded a commercial secret, limiting the opportunities to perform extensive benchmarking and comparison.

### 4.2.3 Analysis of airport cost structures

An analysis of airport cost structure development trends is necessary for defining and justifying future cost structures: e.g. if staff costs continued to grow for the past several decades, they are likely to play a significant role in the cost structure of the future as well. Trends of changes in airport cost structures throughout the years have been explored using method of desk research, by comparing European and United States airports (please see Chapter 4.1.1 for an explanation of the differences in civil aviation history between USA and Europe) as well as unified data provided in global air transport sector reports. Based on the results of this desk research and using expert judgement of the project team, a set of unified cost pies of airports will be provided in this chapter for the periods 1989-200 and 2001-2011.

The analysis of global airport costs structures is performed by comparing the trends in the periods 1989-2000 and 2001-2011. The data samples were extracted out of annual reports of U.S. airports with commercial services (508 such airports in the year 2006[16]), 19 European airports and 6 airports from other parts of the world (see [1], [12], [3], [10], [22], [16], [7], [2]). The data covered both small and large airports; it was therefore necessary to compare airports costs expressed as a percentage of total costs (instead of absolute costs) in order not to distort the reliability of the research results. An average cost structure of for an airport worldwide was composed using data from airports around the globe, which included airports of all sizes. No evidence was obtained that major differences in cost structures exist between large and small airports. Figure 4.4 indicates the changing cost structure of airports worldwide in the period of 2001-2011 compared to 1989-2000.

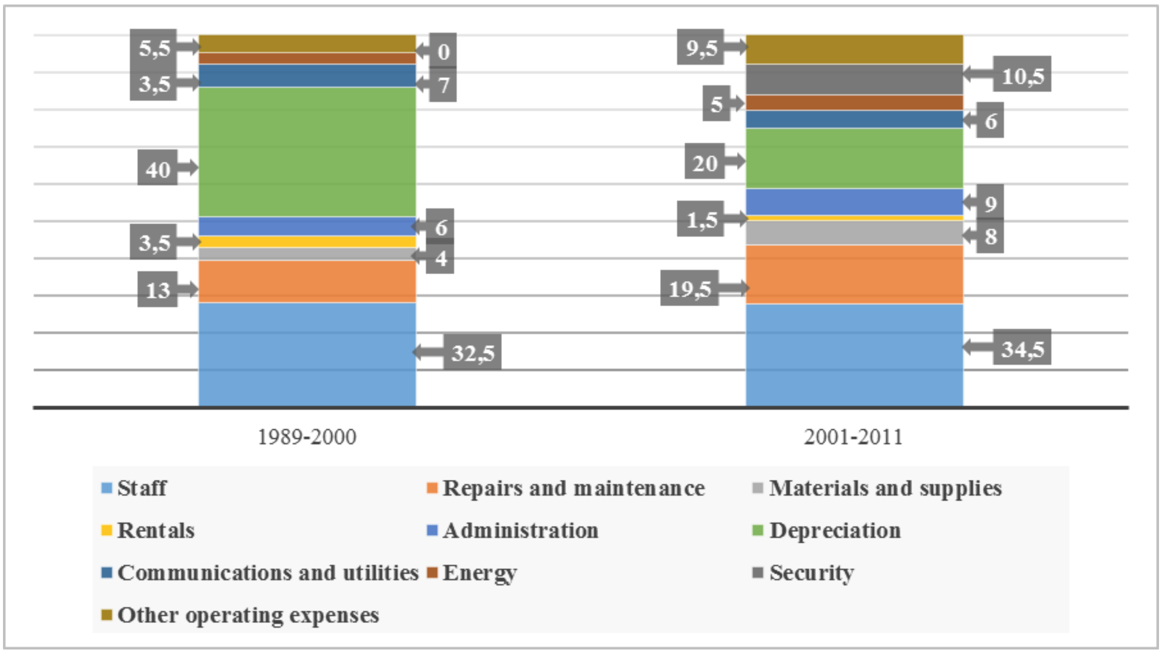



Figure 5: Cost structure of the airports worldwide during the period of 2001-2011 compared to the period of 1989-2000, values as a percentage from total costs

Based on the above figure, a few remarks are in place. First of all, the **costs of staff** typically are 30 to 40 per cent of total costs. Staff costs correlate directly with passenger numbers, which are constantly increasing. Technology is not yet capable to replace human staff and share of personnel costs remained consistent during the period of 1989-2011.

The main changes can be found in the share of the **repairs and maintenance costs** and the **depreciation costs**. The airports expenditure on depreciation has decreased during the years 2001-2011 while the share of repairs and maintenance costs have increased compared to 1989-2000. One of the main factors contributing to this change is the age of airports – a significant number of airports was built prior to the year 2000 and during the last decade the number of airports was decreasing, yielding lower depreciation costs since less investment was necessary to build new infrastructure. Aging and modernisation of infrastructure contributed to increase in maintenance costs. More strict safety rules (safety standards set by EU, ICAO and other institutions) valid worldwide also contributed to additional maintenance activities and costs.

The **costs of security** as a separate part in the costs structure emerged in the period of 2001-2011. It shows that a need of security has arisen in the airports worldwide after the 9-11 event in the United States. Security costs are highlighted as a separate part in the total costs in the last decade and it is believed (as reported by IATA [19]) that expenditure on security will only grow in the near future. At the same time, the increased costs of other operating activities gained more leverage in the total costs structure and lowered the importance of depreciation costs as part of total costs.

The general proportions between cost categories as part of the total cost structure remained similar during period investigated (1989-2011). Slight changes of one costs element did not rearrange the total costs structure drastically; e.g. the introduction of security costs. Based on the carried out desk research, the assumption seems warranted that there seems to be no indication of significant change in the overall airport costs structure for the upcoming several decades.

### 4.2.4 A unified cost structure of airports

In this section, a unified cost structure will be given based on data gathered by means of desk research for the period of 2005-2012. In this cost structure, the security costs are highlighted as a separate part of the total costs in the last decade and it is believed that expenditure on security will only grow in the near future. At the same time, the increased costs of other operating activities gained more leverage in the total costs structure and lowered the importance of depreciation costs. See **Error! Reference ource not found.** below for the unified airport cost pie for 2001-2011.

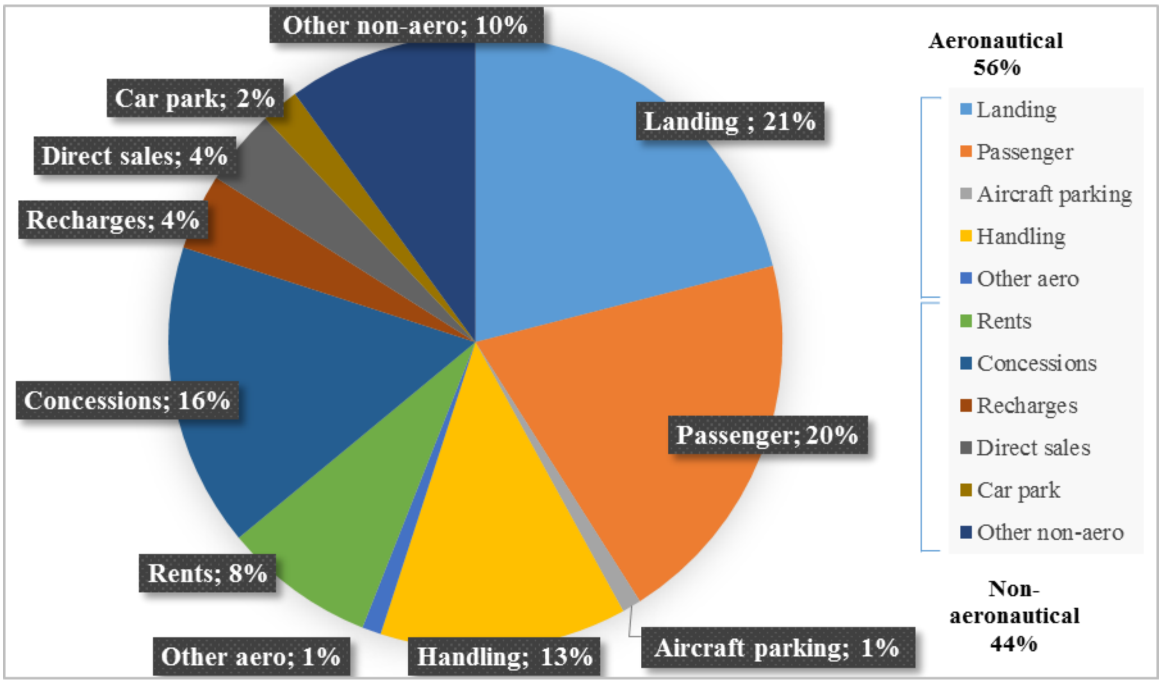



Figure 6: Unified airport cost pie for the period of 2001-2011

Source: Composed by the project team using data from [10], [16]

The unified cost structure represents the average global airport for the period of 2001-2011. The cost categories chosen can be regarded typical for an average-sized airport. Values are provided with ranges for a more accurate model. The following comments should be made regarding this methodology used to produce this figure:

- Repair and maintenance costs correlate with costs of materials and supplies. If these services are outsourced, a lower limit of the range is to be used, if not, a higher limit of the range will represent more appropriate proportion. In case of outsourcing, a new cost category may be added or these costs are accounted under other operating expenses.
- Expenditure on staff in airports shows the widest range as costs of personnel are very different in airports even in the same country. Typically, staff accounts for no less than 30%-40% from total costs. This proportion is very continuous and differences indicate adoption of specific strategy (e.g. increasing non-aeronautical revenues) or management model. Staff costs in most cases accounted for the largest share of the costs and are regarded as a field for possible optimization due to its flexibility.
- Depreciation costs are provided with moderate range to represent differences in state owned and private airports: the lower limit of 14% is typical for state owned airports as they invest a smaller share of own capital to development, whereas the higher limit of 26% is typical for private airports developing from own capital yielding higher depreciation costs.

### 4.2.5 Analysis of airport revenue structures

Today, some airports focus on cost leadership strategies while others choose differentiation and seek niche markets by focusing on earning additional revenue from e.g. non-aeronautical activities [13]. One of the key challenges for the cost-effective airport is to reduce operational costs, whilst maintaining their level or service and level of revenues. In most cases, costs associated with non-aeronautical activities may be deemed unnecessary, since these activities may generate up to 50 per cent of total revenue. Non-aeronautical revenue is expected to become even more important for the future due to constant pressure from the airlines and passengers to reduce fees associated with aeronautical activities. The CE concept aims to develop an airport concept to reduce costs while preserving both aeronautical and non-aeronautical revenues as well as introducing new revenue sources. Further paragraphs will provide insights based on desk research activities on airport revenue structure and revenue sources.

Revenues of airports consist of two types of income sources: aeronautical (air traffic generated) and non-aeronautical (mostly referred as commercial) revenues. Based on analysed revenue data, tendencies are rather difficult to identify since the composition of revenues in individual airports can show significant variations due to various legal aspects in different countries and different commercial activities carried out by specific airports. A comparison of revenues was carried out between Europe and the U.S. in a similar manner as the analysis of cost structures. Differences occur due to the different business practices of airports, for example, many U.S. airports lease their terminal to airlines and get aeronautical revenues from the rent, whereas in Europe this is less common practice [10]. Despite these possible differences, generally revenues of the airports can be structured as depicted in Table 3.

Table 10: Alignment of airport revenues, source [10]

| AERONAUTICAL REVENUES | NON-AERONAUTICAL REVENUES |
|---|---|
| Landing fees<br>Passenger charges<br>Aircraft parking, hangar provision and picketing<br>Passenger charges<br>Freight charges<br>Apron services and aircraft handling (if provided by airport)<br>Fuel throughput surcharges<br>Passenger, freight and baggage handling | Rent or lease income (from airlines and other tenants)<br>Recharges to tenants (for electricity, water, cleaning, etc.)<br>Concession income (from shops, catering, duty-free shops, banks, car parks, hotels, etc.)<br>Direct sales (shops etc. operated by airport authority)<br>Car-park revenue (if operated by airport authority)<br>Miscellaneous (e. g. interest earned)<br>Non-airport related activities (e. g. land development) |

The Berlin school of economics [22] carried out a study which concluded that there is no common definition framework for reporting non-aeronautical revenues in the accounting literature. Accountants, market researchers and strategic consultants also use different definitions which are then reflected in the different performance results of the same airport. In addition, many airports give only aggregated data about their non- aeronautical revenues or give broad-brushed data where combined components in some cases could be considered as stemming from different sources of revenues [22].

Zenglein and Muler from Berlin School of Economics provide some typical cases with deeper insight into the issue [22]:

- Provision of aviation fuel as well as fees derived from provision of engineering services to shops and associated utility charges could be both included under Utility or Supply services. Depending on one's understanding of non-aeronautical, some parts could be considered as aeronautical revenue while others could be considered as non-aeronautical revenue; however, both are included only one line of the financial report;
- Similar problems occur with real estate concessions or rents. Do these revenue incomes include rents from airlines and aviation related third parties or not? It is certainly disputable if all real estate income can be considered as part of non-aeronautical revenue. The distinction of rental revenue from cargo/hangars and fixed base operators (FBOs) used by the Federal Aviation Administration (FAA) makes this very obvious. But according to other approaches found in annual reports it is not clear if these are just aggregated into revenues from real estate.

These problems make it difficult to compare how airports are performing and how effective new non-aeronautical strategies are achieving presentable benchmark results. Comparing different airports, which account and perceive their non-aeronautical revenues differently, can lead to false findings and questionable conclusions.

Table 10 illustrates the problems mentioned above. In this table for three German airports the percentage of non-aeronautical revenues compared to all revenues is given from three sources: annual reports of airports (2003) and reports for 2005 of The Air Transport Research Society (ATRS) and Transport Research Laboratory (TRL), based on 2003 financial data. [22]

Table 11: Overview of non-aeronautical revenue shares to total for selected German airports, source: [22]

| | Annual Report | ATRS | TRL |
|---|---|---|---|
| Frankfurt Airport | 20,1% | 54,0% | 26,1% |
| Berlin Brandenburg Airport | 40,0% | 43,0% | 36,3% |
| Munich Airport | 42,6% | 67,0% | 32,7% |

This table shows how differently non-aeronautical revenues can be treated. Most notably the annual studies Airport Transport Research Society (ATRS) and Transport Research Laboratory (TRL) make an effort to comprise and analyse international airports using financial performance indicators. Both studies include a large number of airports worldwide, 50 (TRL) and 116 (ATRS). Consequently, the scope of these studies is very challenging and in order to obtain data, compromises in data quality have to be made. But even when only looking at German airports vast differences become apparent as can be seen in Table 10 [22]. As a result, no unified revenue structure for airports (cf. section 4.2.4 detailing the unified cost structure for airports) can be defined.

### 4.2.6 Importance of non-aeronautical revenues

The importance of non-aeronautical revenues steadily increased through the last several decades. To provide better insight into the development of airport revenue structures, an analysis similar to the costs structure analysis was carried out, analysing the following periods:

- 1980-2000, early development period of civil aviation; this period was analysed to identify fundamental cost and revenue trends;
- 2000-2012, the development period of modern aviation as it is now, to define current cost and income structures;
- and 2013-2050, for future forecast.

One of the factors contributing to an increased focus on non-aeronautical revenues is the expansion of market liberalisation, which started in US and was later adopted by Europe and which has induced a fast growing number of low cost carriers (LCC). LCCs push airports to reduce charges with the future promise to bring additional passenger traffic to the airport. Increased passenger flows are a potential source of additional revenue that can be used by airports to stay financially sustainable compensating their losses from aeronautical activities with non-aeronautical ones [22]. De Neufville et al. conclude that airports of various sizes have attempted to increase their income share gained from non-aeronautical because profit margins from this type of revenues are typically higher [9], [22] than that from aeronautical activities.

Analysis of the dynamics of revenue structures is necessary to create a justified unified revenue pie as well as a solid basis for a future revenue forecast. For individual airports this change is easily calculable, but figuring out the global tendencies is rather difficult due to several issues with available data: first of all, as it was clarified in the previous chapter, non-aeronautical revenues are treated differently amongst individual airports and this perception evolved during the last decades; secondly, the share of non-aeronautical revenues varies greatly among individual airports. Publicly available information is sparse; however, reports by well recognised air transport stakeholders are publicly available providing unified data [21], [12], [15], [3], [11], [7]. Data from these reports and other reports analysed in this chapter will be used to define possible revenue structure of future airports. This data will be combined with revenue structure trends from the past for more accurate and justified forecast in the following paragraphs.

Average revenue structure of European airports in 1989, demonstrated in Figure 6, reveals that in Europe non-aeronautical revenues accounted for **44%** out of total revenues.

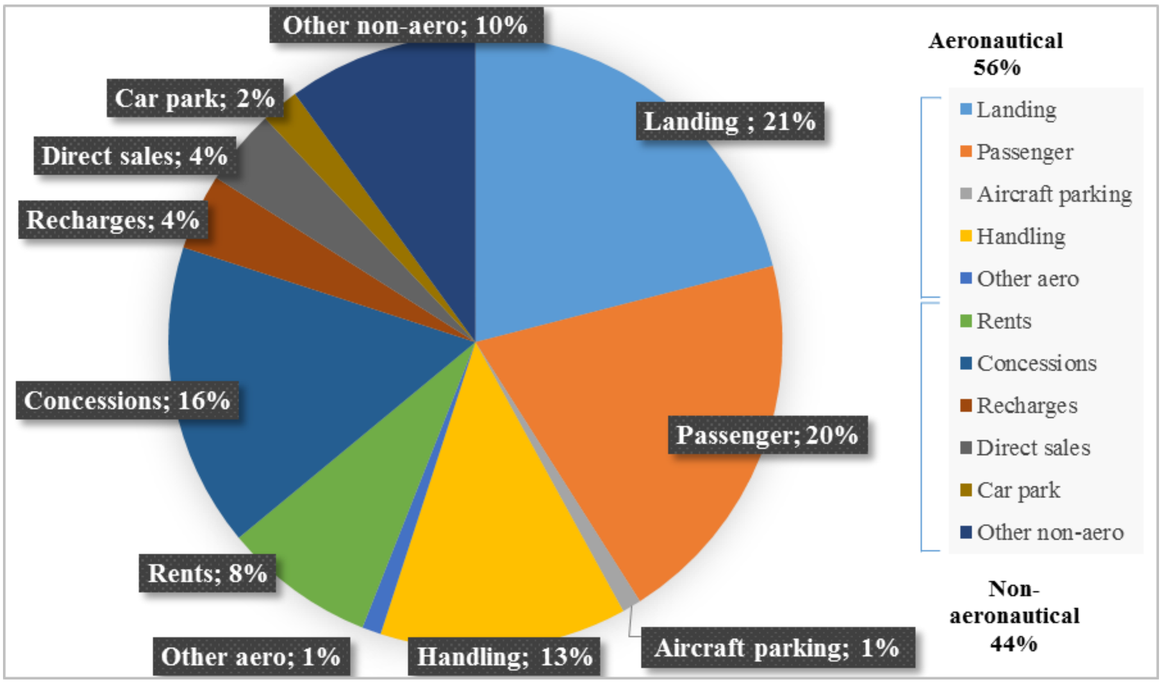



Figure 7: Average revenue structures among European airports 1989[10]

Source: Composed by the project team using data from "The Airport Business" Rigas Doganis

The overall tendency shows a share of 40-50% of non-aeronautical revenues from total revenues for the period of 1975-2000; the further development of commercial airports reveals more variety in the non-aeronautical and aeronautical revenue shares in total revenues. For the period 2001-2011, Table 11 below reveals a much wider range of aeronautical revenue, ranging from 32% up to 71%.

Table 12: Revenue structure of large airports, 2002, source [16]

| AIRPORT | AERONAUTICAL REVENUES AS % OF TOTAL OPERATING REVENUE | NON-AERONAUTICAL REVENUES AS % OF TOTAL OPERATING REVENUE |
|---|---|---|
| Incheon | 28 | 72 |
| Munich | 32 | 68 |
| Paris CDG | 36 | 64 |
| Rome FCO | 37 | 63 |
| Singapore | 39 | 61 |
| Sydney | 40 | 60 |
| Beijing | 41 | 59 |
| Bangkok | 44 | 56 |
| London LGW | 45 | 55 |
| Hong Kong | 45 | 55 |
| Frankfurt | 46 | 54 |
| Amsterdam | 48 | 52 |
| London LHR | 48 | 52 |
| Osaka | 48 | 52 |
| Vienna | 51 | 49 |
| Copenhagen | 52 | 48 |

| **AIRPORT** | **AERONAUTICAL REVENUES AS % OF TOTAL OPERATING REVENUE** | **NON-AERONAUTICAL REVENUES AS % OF TOTAL OPERATING REVENUE** |
|---|---|---|
| Manchester | 52 | 48 |
| Zurich | 54 | 46 |
| Brussels | 62 | 38 |
| Kuala Lumpur | 67 | 33 |
| Milan MXP | 71 | 29 |

Based on the data provided in the Table 11, it can be concluded that the average share of non-aeronautical revenues in 2002 was 49% of total revenues – an increase of 5 percentage points compared to data of year 1989.

For the period following 2002, data provided by Air transport research society [7] is used to yield a unified revenue structure for airports today (2009) and beyond. This data is used both to give insight in the non-aeronautical revenue share of airports today, and provides the basis for forecasting this share for time to come.

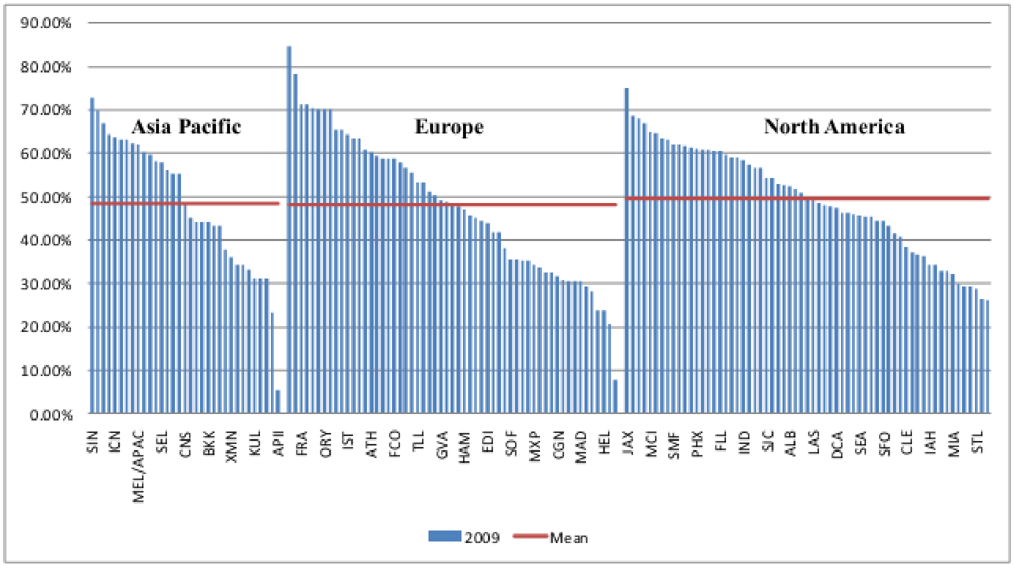



Figure 8: Percentage of non-aeronautical revenues by continent 2009

Averages were calculated using the data and ranges optimised to represent an average airport. Extremes were excluded from the range, as they are not representative (outliers) for defining the average unified airport revenue structure.

Table 13: Percentage of non-aeronautical revenues as part of overall revenues, by airport, year 2009

| | **CODE** | **COUNTRY** | **AIRPORT NAME** | **NON-AERONAUTICAL INCOME, % OF TOTAL INCOME** | **PASSENGERS** |
|---|---|---|---|---|---|
| 1. | BCN | Spain | Barcelona El Prat Airport | 30 | 34,398,226 |
| 2. | MAD | Spain | Madrid-Barajas Airport | 30 | 49,671,270 |

| | CODE | COUNTRY | AIRPORT NAME | NON-AERONAUTICAL INCOME, % OF TOTAL INCOME | PASSENGERS |
|---|---|---|---|---|---|
| 3. | ZRH | Switzerland | Zurich Airport | 30 | 24,337,954 |
| 4. | CGN | Germany | Cologne Bonn Airport | 31 | 9,806,270 |
| 5. | DUS | Germany | Düsseldorf International Airport | 31 | 20,339,466 |
| 6. | MXP | Italy | Malpensa Airport | 33 | 19,291,427 |
| 7. | BRU | Belgium | Brussels Airport | 34 | 18,716,034 |
| 8. | MLA | Malta | Malta International Airport | 35 | 3,506,521 |
| 9. | SOF | Bulgaria | Sofia Airport | 35 | 3,474,993 |
| 10. | KBP | Ukraine | Boryspil International Airport | 36 | 8,029,400 |
| 11. | KEF | Iceland | Keflavík International Airport | 36 | 2,112,017 |
| 12. | PRG | Czech Republic | Prague Ruzyně Airport | 37 | 11,643,366 |
| 13. | LIS | Portugal | Lisbon Portela Airport | 43 | 14,805,624 |
| 14. | BHX | United Kingdom | Birmingham Airport | 44 | 8,616,296 |
| 15. | EDI | United Kingdom | Edinburgh Airport | 45 | 9,385,245 |
| 16. | LHR | United Kingdom | London Heathrow Airport | 48 | 69,433,230 |
| 17. | HAM | Germany | Hamburg Airport | 49 | 12,962,429 |
| 18. | GVA | Switzerland | Geneva International Airport | 50 | 13,130,222 |
| 19. | LJU | Slovenia | Ljubljana JožePučnik Airport | 50 | 1,369,485 |
| 20. | MAN | United Kingdom | Manchester Airport | 52 | 18,892,756 |
| 21. | LGW | United Kingdom | Gatwick Airport | 53 | 33,674,264 |
| 22. | TLL | Estonia | Lennart Meri Tallinn Airport | 53 | 1,913,172 |
| 23. | MUC | Germany | Munich Airport | 55 | 37,763,701 |
| 24. | STN | United Kingdom | London Stansted Airport | 57 | 18,052,843 |
| 25. | FCO | Italy | Leonardo da Vinci-Fiumicino Airport | 59 | 3,769,346 |
| 26. | AMS | Netherlands | Amsterdam Airport Schiphol | 60 | 49,755,252 |
| 27. | ATH | Greece | Athens International Airport | 60 | 14,446,963 |
| 28. | CPH | Denmark | Copenhagen Airport | 61 | 22,725,517 |
| 29. | IST | Turkey | Atatürk International Airport | 65 | 37,452,187 |
| 30. | OSL | Norway | Oslo Airport, Gardermoen | 67 | 21,103,623 |
| 31. | ORY | France | Paris Orly Airport | 70 | 27,139,076 |
| 32. | FRA | Germany | Frankfurt Airport | 72 | 56,440,000 |

The initial range of data indicates that non-aeronautical revenues of individual airports vary within the range of 30% to 70%. The average for the non-aeronautical revenue share is 47%, close to that of 2002 and 1975-1976. These average indicators for the past four decades (1975-2012) suggest a tendency that non-aeronautical revenues will continue to account for a significant share in total revenues for the time to come.

Development trends of airport revenue structures are usually broken down into revenues generated by specific activities (for internal reporting purposes). Public reports are rarely available providing this level of detail, as commercial activities and specific revenues are considered a commercial secret. A comparison is available using unified data provided by the Airport Council International (ACI), the worldwide federation of airport operators and stakeholders. The results of a survey carried out in 2009 have been analysed. Data was gathered from 646 airports that together handled 3.23 billion passengers or about 67.5% of worldwide traffic in 2009, thus providing presentable and comprehensive results and unified data. **Error! Reference source not found.** below yields the resulting revenue structure istinguishing between 12 different revenue categories.

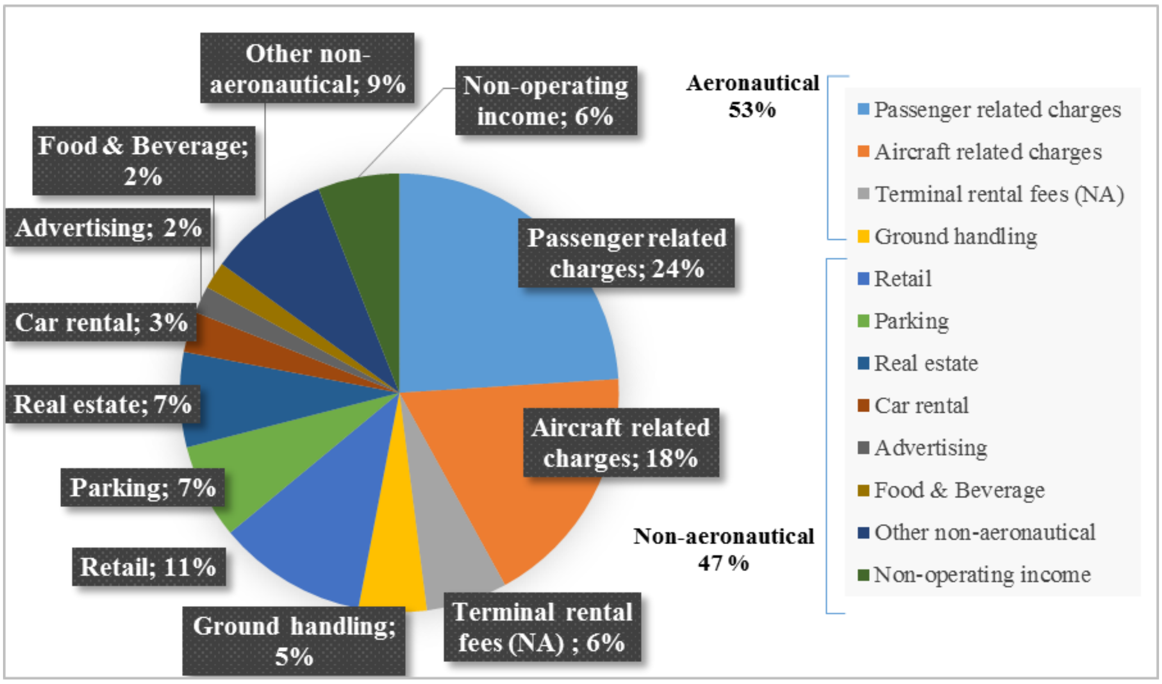



Figure 9: The average revenue structure among world airports 2009[2]

The overall proportion of non-aeronautical revenue in the revenue structure is **46.5%** (which corresponds with previous data). Non-aeronautical activities are of great variety within each particular airport. Additional research was carried out in order to identify factors contributing to non-aeronautical shares of revenue for deeper insight into future trends.

An analysis of the relation between non-aeronautical revenues and passenger numbers was carried out to verify the hypothesis that larger airports (in terms of number of passengers) generate more revenues from commercial sources (as a percentage of total revenues) compared to small airports due to a more developed infrastructure of commercial services and possible economies of scale [15], [10], [22], [16], [7], [2]. This analysis revealed that airports are individual and unique in setting and many variables need to be taken into consideration to objectively evaluate the airport's performance. A number of factors influence the ideal balance between aeronautical and non-aeronautical revenues, or the best (in terms of profitability) share of non-aeronautical revenues as part of total revenues. The most important factors are presented in Table 13.

Table 14: Factors affecting share of non-aeronautical avenue out of total revenue

| PASSENGER AND AIRLINE STRUCTURE | INFRASTRUCTURE | REGIONAL FACTORS |
|---|---|---|
| • Share of international passengers;<br>• Share of LCC passengers;<br>• Share of transfer passengers;<br>• Destination composition. | • Airport architecture;<br>• Available commercial real estate;<br>• Transportation infrastructure. | • Economic development;<br>• Regional infrastructure;<br>• Purchasing power;<br>• Population density. |

## 4.3 Reference basic airport characteristics

Apart from the cost and revenue structure employed, other airport characteristics are also relevant when developing the Cost-Effective airport of 2050+. In the previous section, the average cost and revenue structures of current-day airports, and related development trends, were outlined. In this section, a brief overview is given of more hard-core main elements of the reference, baseline airport. Taken together, both cost & revenue structures (section 4.2) and the physical decomposition and process organisation (this section) define the reference airport. All concept solutions proposed by the Cost-Effective concept (see chapter 5) have been developed and will be assessed (chapter 6) against the background of this reference/baseline/unified/average airport.

The main airport elements (both the physical components and the procedures/processes in place) relevant for developing the CE airport of the future are described below.

**Runways and taxiways**

The reference airport is a medium size airport bearing 1 or 2 runways (preferably parallel) which are connected with the apron by several taxiways and rapid exit taxiways. In case of parallel runways they are able to operate parallel take-off and landing.

The Instrument Landing System (ILS) at the runways is at least Category II. The length is around 3500 meters and the width is around 45m.

The fire-fighting capability is Level 5.

**Terminals**

The passenger terminal serves about 10-15 million passengers per year, consisting mainly of origin-destination passengers, with a limited amount of transfers. The terminal is capable to accommodate international and domestic flights (and Schengen and non-Schengen operations for European purposes). It should have jet bridges and remote stands as well. The minimum connecting time (MCT) should be around 45 minutes. More specifically, the average terminal has the following features:

- 1 terminal building with jet bridges and remote stands
    - Number of jet bridges: ~ 15
    - Number of remote stands: ~ 25
- Number of security gates: ~ 14
- Number of check-in desks
    - 'Normal check-in': ~30 counters
    - Self-check-in: ~ 12
- Access to intermodal connections
    - Rail
    - Public bus transport
    - Motorway

**ATM**

It is a Controlled Airport which operates 24h a day. It supports ATM communication needs (radio frequency, on-line) and supports ATIS creation and broadcasting. It has published standard departure and arrival procedures.

Tower control (ATCT) is available and Terminal Area Control (TMA) is generally available.

Generally, radar services are supported.

**Intermodal connections**

The intermodal ways of transportation identified for the baseline airport are:

- Car. Reference distance: 100 Km
- Taxi. Reference distance: 100 Km
- Bus. Reference distance: 50 Km
- Metro. Reference distance: 25 Km
- Mid-range train / Light Train. Reference distance: 100 Km

**Energy supply**

The airport must have auxiliary and back up (internal) energy sources which are capable of providing sufficient energy to:

1. ATM facilities
    2. Safety equipment
    3. Security equipment
    4. Terminal building (operations)
    5. Apron and runway lighting

# 5 The Advanced Cost-Effective airport concept

This chapter will detail the novel ideas that may lead to an airport being cost-effective to the farthest possible extent in 2050. Due to the relatively large time horizon, the current state-of-the-art, as is, cannot form the baseline for these ideas: they need to be introduced against a background envisioned for 2050, significantly different from the environment we are living in these days. Therefore, prior to detailing the novel concept elements, the state-of-the art envisioned for 2050 will be presented along with a justification of the qualifying factors, where applicable, in section 5.1.

Next, in section 5.2, a structured concept of the 2050 Cost-Effective is developed. A service-oriented methodology will be presented to identify airport services suited for CE improvement, followed by a morphological grid analysis to list possible solutions to exchange current ways of service to operate more efficiently. This is done by analysing the feasibility of total or partial elimination of each particular service, asking the question whether the service is at all necessary by 2050. The term “service-less airport” is introduced, as the most extreme (however theoretical) solution for cost efficiency that will serve as a basis for rebuilding the airport of the future from the building blocks of elementary services. After filtering out unnecessary services, a specific set of concept solutions is developed for each remaining service based on the outcomes of an expert brainstorm held at SLOT consulting Ltd.

In section 5.3, all proposed concept solutions are grouped in four main categories: Intermodal SWIM solutions, ATM related solutions, turnaround solutions, and terminal related solutions. Next, all solutions are further elaborated.

Finally, in section 5.4, the different concept elements will be integrated in an encompassing story of the Cost-Effective concept by means of a door-to-door travel scenario. Furthermore, the effects of the integrated concept will be shown on the whole layout on the airport, the terminal building and the turnaround process.

## 5.1 State-of-the art-operations in 2050

### 5.1.1 Airplane of 2050

By 2030 the proportion of people living in cities from total population is expected to increase to 59% with about 5 billion people living in cities. By the year 2050 over 70% of the world’s population is expected to live in cities [4]. The main growth rate of urban dwellers is expected to be in developing countries, mostly in China and India.

Urbanisation is generally considered to be one of the main drivers for globalization and economic growth; economic growth, in turn, will have a positive impact on the demand for mobility in general, and the demand for air transport in particular [3]. According to a forecast provided by ACARE [12] the global economic growth rate is expected to be about 3% per year. The wealth in developing economies such as Brazil, Russia, India and China is growing. A “middle class” is emerging in the developing countries with people demanding progress in terms of access to technology and mobility. Their desire for travel will be driven by their (most likely rising) financial possibilities.

The **Liberalisation** of the air transport market which previously contributed to increased competition and the rise of low cost carriers also contributed to unprecedented growth of passenger and freight volumes in the aviation sector. Further liberalisation of air transport in currently still regulated markets is expected to drive traffic growth in parts of Asia and Africa in the coming years [3]. Continued growth of low cost carriers is also expected, especially in Asia [3].

At the same time, a stronger focus on the **environment** is expected impacting costs of airlines and airports as. The depletion of many resources and notable effects of climate change will spark a shared awareness of the importance of sustainability amongst m the public, expecting the air transport industry to do all they can to become as sustainable as possible [12].

**Technology** changed the face of aviation through the last decades and continues to influence the way every activity is carried out. It is foreseen that in the future, technology will continue to have a strong impact in automation and ultimately in the cost structure. New technology related solutions will typically come with high investment costs but usually the balance is quite positive when the decrease in operational costs and the possible increase in revenues are also considered.

In order to understand the novelties of the future airport, the future aircraft should be studied and described as well. The following description is based on the Global Market Forecast study of Airbus [3].

In the future smart, lightweight materials will be used for the structure of the aircraft which enables for example a new fuselage concept including double doorways for faster boarding/ de-boarding. The ‘boarding gate’ will be on board of the aircraft whilst once entering the aircraft; the passengers will be required to identify themselves by biometric devices.

Composite materials will be used for the cabin which will be covered by biopolymer membrane shielding enabling the controlling of natural light, humidity and temperature. The materials used within the cabin (e.g. seats) will be self-cleaning, while smart energy solutions such as energy harvesting (collection of body heat by the seat) will reduce the energy needs.

The bionic structure in combination with responsive membranes in the cabin will be able to identify and respond to the needs of each passenger.

Finally, there will also be some major differences between short- and long-haul purpose built aircraft:

- Short-haul planes will carry around 160-180 passengers. As the main goal of such aircraft will be to minimize as much as possible the time spent on ground, they will be equipped with automated self-servicing equipment such as boarding/ de-boarding facilities. They will not carry catering equipment, as the travel time will be at a minimum.

- The long-haul aircraft will be larger in size and will carry around 500 passengers. The main aim of these types of planes will be to offer a comfortable journey for the travellers. They will carry catering equipment and the available space for one person will be maximized as much as possible. Due to its size and to save space and weight, they will not carry self-servicing equipment as the short-haul aircraft.

### 5.1.2 Communication in 2050

SWIM (System-Wide Information Management) is an on-going joint (North-American / European) advanced technology program designed to facilitate greater sharing of Air Traffic Management (ATM) system information, such as airport operational status, weather information, flight data, status of special use airspace, and National Airspace System (NAS) restrictions [19]. SWIM will support current and future NAS programs by providing a flexible and secure information management architecture for sharing NAS information.

By 2050 SWIM will be completely implemented and available. Most aircraft will have the ability to digitally communicate throughout the whole period of flight and on the ground. The need for voice communication will be minimized to be applicable to emergency situations only.

### 5.1.3 Technology in 2050

The air transport industry always was, and hopefully will be, the industry that uses the most advanced technology available in order to achieve increased safety, security and efficiency. To envisage the cost efficient airport of 2050 we have to wonder ourselves which areas of technology development will make it possible for airports to achieve that.

Airports are the areas where airlines conduct activities such as landing and take-off, boarding and de-boarding of passengers, and loading and unloading of cargo. To accommodate these operations while maintaining security, safety and efficiency, airports have to apply a range of advanced technologies which impact the cost efficiency of airport operations.

A breakthrough in any technology that is extensively applied to airport operations could bring considerable changes in operations and cost effectiveness. Therefore, it is important to assess those fields of technology that could bring such advance.

The technologies considered in this section are in the area of 1) navigation, 2) of aircraft servicing and 3) of passenger and cargo handling.

There is a range of equipment supporting the approach, landing, taxiing and departing of aircraft. For example by enhancing aircraft capabilities towards “self-servicing” equipment required on the ground is reduced. By application of synthetic vision in cockpits, the construction, maintenance and usage cost of sophisticated lighting systems is minimized whilst the crew’s situational awareness is increased. By satellite based navigation, the need for ILS and runway and taxiway lights will be less mandatory and eventually these types of equipment may become obsolete.

These changes will impact different airport sizes. The large, well equipped airports will be able to lower their buildings, operating and maintenance costs and small secondary airports will have an opportunity to expand faster, avoiding these costs. Larger airports adapt to changes in technology slower, as large scale investments are required as well as dramatic changes in (infra)structure and operations; in contrast, smaller airports are quick to adopt changes, but have limited access to investment funds.

Another area of implementing new technology is security at the terminals. Due to security reasons the passengers are lead through different pathways with artificial bottlenecks to allow for a variety of different checks. Currently the terminals are built to accommodate such security related procedures as check-in, passport control, security check, manual check of hand luggage and passengers, etc. Due to the fact that the security requirements have become more rigorous today one can often observe a guardrail in front of the security check points created from ribbons indicating that there might be a long queue. In many places the paper based procedures still in use as well as the use of inadequate (to the throughput and the number of passengers) security equipment does not help the situation. The current security procedures are basically very old-fashioned: the passenger is separated from all the baggage and cloths as much as possible (shoes, coats, belts, etc.) and then they are screened by X-ray machines and the passenger is checked manually.

New developments in security technology could support a different approach in security procedures. As developed within the ATOM FP7 project [18], enhanced terahertz technology combined with the passive radar and enhanced video surveillance could provide full area coverage of the terminal. This coverage is made possible by a pervasive security system and makes this maze obsolete supporting a simple, and thus cost-effective floor design for terminals and a fast and easy route to the aircraft for the passengers. Although such radical new solutions mean an investment cost at the beginning, the operational costs can be reduced significantly in the long term. Besides, as time is money (and it will be even more the case in 2050) any solution which makes an airport time efficient has also a positive impact on the possibilities for revenue increase, since a better functioning airport can get set higher prices for its services, or can alternatively keep its prices at the same level whilst improving service provision, thus attracting more passengers.

### 5.1.4 Influence of technology on everyday life in 2050

The identification of passengers and the provision of location-dependent directions to their aircraft could be done by enhanced ICT solutions making paper based identification obsolete. Even today’s smart devices tend to incorporate previously separated services like television, internet and phone communication and are expected to become the standard. The already available NFC (Near Field Communication) technology could go through further evolution and provide further services making paper based identification completely. Passengers could be then identified, security screened and provided with the necessary information (indoors navigation system providing navigation to the required gate and information on needed time to reach at current pace to the gate and boarding times) automatically. Depending on the level of sophistication and additional requirements, this would however require a large IT performance both from airport systems (to handle information about thousands of passengers simultaneously) and from the personal equipment of the passengers. The current silicon based technology might be reaching its limits. The main enabler for these changes could be the carbon nanotube-based technology that is expected to provide ten times more powerful processors with the same energy consumptions, or the diamond-based technology that is under development now for fifteen years.

The further evolution of the in aviation industry well-known SWIM and solutions in other fields based on similar principles, such as used in banking and government, could be introduced and could provide a solid background for the two way communication enabling on the one hand, identification of the passenger, check-in and boarding and provision of necessary information for the passenger on the other hand.

Another field of interest to cost effectiveness could be the implementation of new technologies such as hybrid lighting systems providing natural light inside the buildings during the day by use of fibre optic cable bundles to channel the sunlight into the buildings combined with artificial light or spry-on solar-power cells using nanotechnology providing electricity practically from any surface covered by it even on rainy days.

The use of green technologies is important not only to support sustainability and lower the production cost of energy, but also, according to the Vision 2050 document of The World Business Council, because Sustainable Development will be supported by government policies while other technologies might be penalised. Therefore, implementation of new sustainable technologies will result in cost savings just by its implementation.

### 5.1.5 Airport of 2050

In the (far) future, air transport can be assumed to become increasingly connected to other modes of transportation to become part of a large intermodal transportation network chain. There will be larger intermodal hubs, where the different modes of transportation will be connected. These hubs will take place at an airport, a train terminal or in the city centre. Technologies that have been implemented today at only the most advanced airports will be much more widespread in the future.

#### 5.1.5.1 Ticketing

It is most likely that the current ticketing will disappear: the tickets will be purchased online and will become valid for a whole journey (including train, metro, etc.). There would be no ticketing anymore solely for air transport.

#### 5.1.5.2 Check-in

Check-in will take place at the first stop of the journey and will not require any check-in desks with check-in agents. It will be done by personal communication devices either by a scanner which reads the QR code or a device which is able to communicate with the smart phone and automatically detect it to perform check-in.

In 2050 the whole transportation chain will be secured and the airport will be part of an intermodal transportation chain. These interchange points will provide access to the public city transport (bus, tram, metro), to the airplanes, to the train and to the public roads (high way, motorway). In this sense an intermodal connection point can be placed at an airport as well.

In the future a further spread of self-tagging and automatic baggage drop-of systems – see Figure 5.1 below, can be expected.

Figure 10: Baggage drop-off system at Schiphol-Amsterdam airport

An automatic baggage drop-off system also enables remote self-check-in and can be used at hotels or car parks. It automatically checks baggage’s weight, dimension, shape and label bar code. It also includes a pay terminal where the cost of the overweight can be recovered. The bag is photographed and tracked from the moment of entry.

#### 5.1.5.3 Security check

According to the IATA the current security-check system isn’t effective enough, and wastes energy and time, examining numerous bags rather than high-risk passengers. [6]

For the *security check* several alternatives are possible, such as:

- Passengers will be assigned to a travel profile: the ’trusted’ passengers will go through a more simple security check than the ’new’ passengers.

- Biometric identification: the security check can be combined with a biometric identification (either retina or fingerprint identification) which allows the frequent passengers to go through a lighter security check.
- Terminal covered by radars: the terminal building can be covered by THz and/or GHz radars which detect any weapons and dangerous materials upon entering any terminal, thus security gate will not be needed.
- Behavioural screening: currently WeCu Technologies develops an automated system for the detection of a person’s intent. This technology is based on the fact that, in connection with an involvement in an act or knowledge with a topic, people “carry” in their minds bits of facts connected to that issue. These bits of information form a set of associations which are relevant only to that specific topic. When these individuals are exposed to stimuli that “symbolize” or hint at the related associations, they will react in an emotional and cognitive way, which originates from their familiarity with the relevant issue. The system identifies this connection by detecting the person’s physiological response through non-intrusive biometric sensors. If the stimulation is relevant to the checked person, he or she will demonstrate a suspicion-arising response.

#### 5.1.5.4 Passport control

In the future passport control will make less sense because the boundaries between some countries will disappear (e.g. Schengen). At the same time, there will always countries where visa and/or identification are required before entering.

For the identification of the persons biometrics-enhanced passports and identity cards will be applied generally. New technologies enable contactless card scanning and very high speed data interfacing which will reduce the time needed for identification and boost security.

#### 5.1.5.5 ATC procedures

In regard to ANSP, the SESAR ATM Master Plan [17] foresees that 4D trajectory and aircraft Capabilities Levels 2, 3 & 4 will be used in the near future, which will change current service provision. These will be provided mostly by the aircraft itself and not by ground-based service providers. A high level of automation is also expected.

Furthermore, one of SESAR’s high-level aims is to reduce ATM costs by 50%. This will have an effect on ATM costs included in airports’ fees and charges, although, a large portion of the cost reduction will be passed on to the airlines.

#### 5.1.5.6 Cost structure: future trends

The cost structure introduced below will be based on the factors influencing air transport as identified in Chapter 4.1 and the unified cost structure for an average airport as detailed in Chapter 4.2.4. The calculation of the forecasted cost structure is further based on an extrapolation of past growth trends with respect to Chapter 4's reference airport. Comments will be provided to justify the forecasted cost structure.

As discussed in Chapter 4, the average cost structure of airports did not show dramatic changes in the last 30 years: overall costs increased in value, but proportions remained continuously similar throughout the analysed period. Therefore, there is no indication that *drastic* changes cost structure proportions will occur in the future. This moderate approach was used to model and calculate the future cost structure of airports. **Error! Reference source not found.** below yields the forecasted cost tructure for airports in 2050.

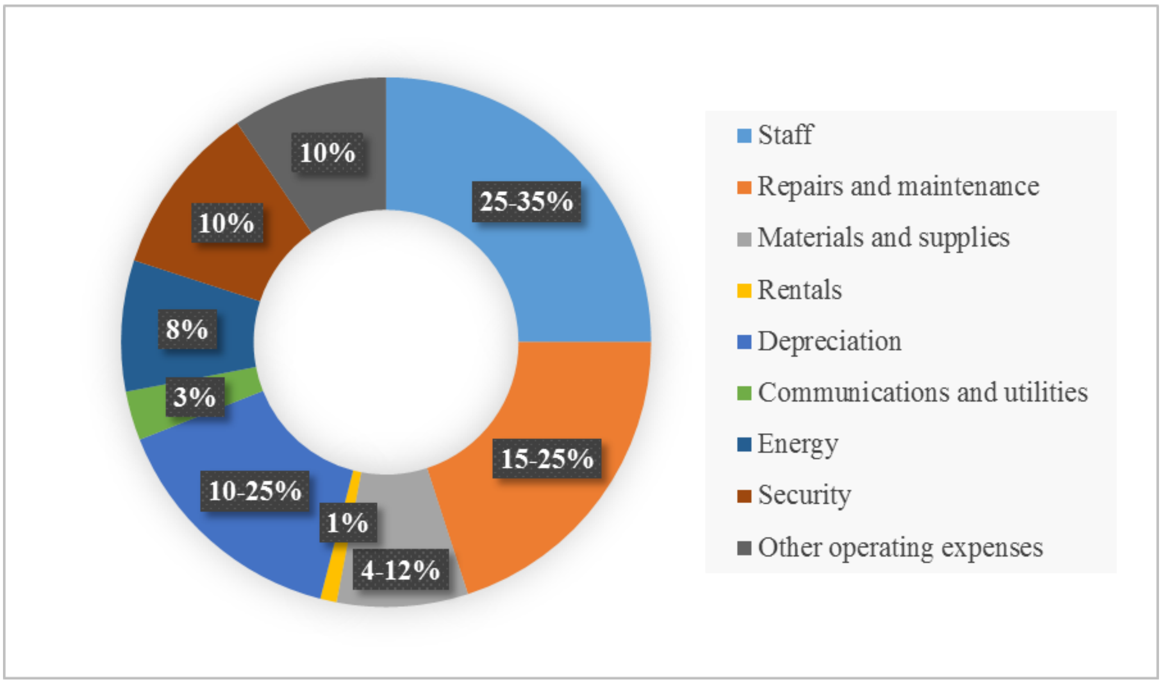



Figure 11: Forecasted cost structure of future airport

Based on the above figure, a few remarks are in place. First of all, the **staff costs** are expected to reduce, but remain the dominant share of cost pie. As airports are forecasted to increase in size and serve larger passenger flows, a significant number of staff numbers will be required to supply demand for service. The cost share accounted for by staff is not expected to increase as emerging technology is capable of replacing human operations by machines in many places; the investment costs required for such equipment will however create a long-term increase in depreciation and additional increase in maintenance costs. Moreover, a trend of increasing non-aviation service revenues is emerging from the increase in market share of low-cost airlines; additional staff will be required to provide these additional services. These costs are also directly related to outsourcing services (outsourcing reduces costs of staff but increases other costs).

**Repair and maintenance costs** are expected to increase, as more complicated technologies in larger volumes are adapted as part of the airport infrastructure. Continuously increasing pressure on safety rules contributes to more routine work regarding preventive checks of the equipment and infrastructure. These costs also correlated with outsourced services.

**Material and supply costs** are expected to maintain a constant share of the cost structure, as material costs in markets are increasing but simultaneously more efficient technologies are adopted, leading to a larger gain from the same amount of materials.

**Depreciation costs** are expected to increase as more and more airports are expected to become privately owned instead of state owned and investment is made from own capital. Also, due to a forecasted expansion of airports and the installation of new technologies, large investments are expected which will inevitably reflect in higher depreciation costs.

**Energy costs** are expected to increase due to forecasted lack of resources in the future unless new cost-effective energy sources will be developed. Overall, an increase of energy costs is assumed based on increase evidenced in the past decades.

**Security costs** are expected to continue increasing. Due to an increasing demand of stricter but faster security and less invasive procedures of passenger and freight check, investment to staff and equipment will be required yielding an increase in security costs.

#### 5.1.5.7 Revenue structure: future trends

As discussed in Chapter 4.2.5, the future revenue structure of airports is rather difficult to predict, since more variation is possible than in the cost structure. After all, while all airports have a certain set of similar operations and corresponding costs, revenues depend on the many specific activities each airport employs. Each airport negotiates for its own landing fees and passenger fees, providing different services to passengers and freight carriers and yielding different revenues. Due to such diversity of airports, the only justifiable trend for the airport revenue structure is the proportion of aviation and non-aviation income: as discussed in Chapter 4.2.5, the trend over the past several decades has been a stable division of 30 to 50% for non-aviation revenue against 50 to 70% of aviation revenue. Despite the fact that the share of non-aviation income did not increase, however, its overall significance increased: the rapid invasion of low-cost airlines contributed to a general growth in passenger numbers and attracted travellers that previously did not use air transport at all due to its large costs or limited availability. Low-cost airlines attract passengers to the airports and might increase passenger volumes of particular airports rather rapidly over short period of time. The proliferation of low-cost airlines increased overall rivalry between airlines which resulted in airline pressure on airports to decrease their fees in order for airlines to gain competitive advantage. Aviation revenues become more and more difficult to sustain and since they can no longer ensure the profitability of airports, additional revenue sources are necessary to sustain income levels and cover constantly growing costs. **Error! Reference source not found.** below yields the forecasted revenue tructure for airports in 2050.

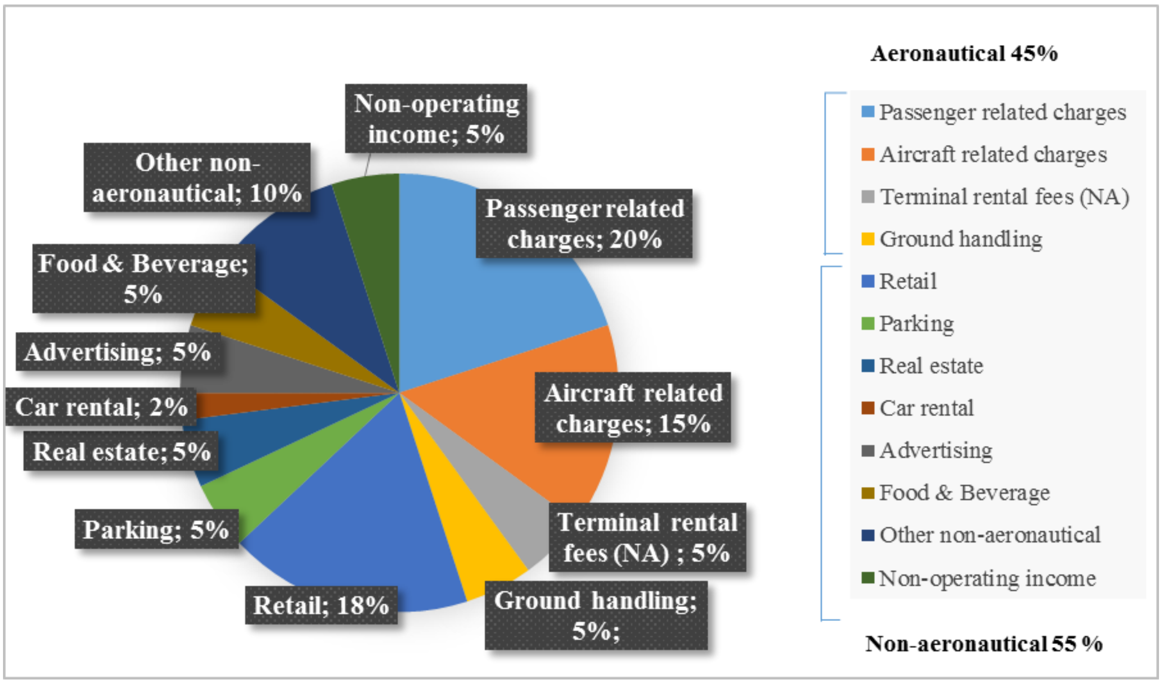



Figure 12: Forecasted revenue structure of future airport

**Aeronautical revenues** are expected to decrease their share of the total revenue; however the volume of aeronautical revenues is expected to increase due to a continuous growth of passengers and freight. Airports are expected to increase in size as well and serve more flights; therefore a significant share of revenues is still expected to come from aviation related services.

**Non-aeronautical revenues** are expected to grow in some fields and decrease in other. Less income may be expected to come from parking service and car rental, as public transport use is – at least in Europe - heavily promoted whilst the use of private cars is getting more and more constrained. Advertising revenues should increase as larger passenger flows increase the effectiveness of adverts. Other revenues from additional services should increase as well, since an increased number of passengers increases the probability of additional purchases. In the figure above, a tendency is shown in which airports become “secure shopping malls” and entertainment and conference centres in the far future.

## 5.2 Airport concept development

The Cost-Effective concept development differs from Time-Efficient and Ultra Green in the orientation of its concept modelling approach. Whereas the TE and UG concepts rely on an infrastructure- and process-oriented view; for CE, an orientation on the cost and revenue structure employed by the airport is of paramount importance as well. All changes in airport processes and infrastructural elements may imply additional costs and/or additional revenues. In order to focus on the impact of concept ideas on costs/revenues, the CE concept has adopted a service oriented view, defining the term “service” as:

*'Infrastructure or activity that is offered by a provider entity and is publicly available on a free or business basis'*

By following this service oriented view, both infrastructure and processes can be investigated under the same umbrella, using the same methodology, from a cost-efficiency perspective. In this view, services of an airport include the runway as well as any process regarding the handling for instance. Services may have an initial investment and daily operating costs identifiable in the spending portfolio of an airport, these can thus be individually investigated from a particular cost-sensitive aspect.

It has to be kept in mind that cost-efficiency is oriented both towards costs as well as revenues. Services with high profitability may be qualified for the cost-effective concept even if they involve high operational costs.

Since the lowest-costing service is simply no service at all, the proposed core methodology for the Cost-Effective Airport Concept introduces a rather radical approach: it starts from the baseline of a "Service-less Airport". Based on this Service-less airport, the Cost-effective airport is build up following a number of steps (detailed in the sections that follow):

6. **Service-less Airport concept definition** (see section 5.2.1)
   Starting point (strictly theoretically) is a plain field of grass without any services as a commercial airport
7. **Identification of services** (see section 5.2.2)
   From the cost-revenue structure of today's airports, identify the services that are provided to the customers. Data from today's low-cost airports can be well utilized here as the closest available model to the cost-effective airport of the future.
8. **Brainstorm to evaluate existing and elicit new CE solutions for these services using Morphological Grid Analysis** (see section 5.2.3)
   First, by means of expert consultation, a set of new Take the services one-by-one, investigate them individually by posing the following questions:
   a. What are the key enabler technologies that are needed to substitute a particular service?
   b. Are there any signs that make the general availability of those technologies expected by 2050? (Query research programs like SESAR, NextGen, etc.)
   c. If the service cannot be omitted, to what extent can it be reduced?
9. **Asses the KPI impact of the new CE solutions** (see section 5.3)
   First, group all CE solutions developed in the previous step into four categories: intermodal SWIM, ATM related solutions, turnaround solutions and terminal related solutions. Then elaborate the solutions in each group in detail. Finally, add each group of solutions to the service-less airport.
10. **Overall validation of the new, Cost-effective Airport Concept** (see section 5.4)
    Finally, investigate the overall cost-effectiveness of the integrated set of new services. Is the overall concept feasible? Is the reduction/elimination of any services raised extra costs somewhere else?

### 5.2.1 Service-less airport concept definition

A service-less airport is defined as an airport where only a green-field is provided and no services are offered to the stakeholders (e.g. airlines, passengers, flight carriers, industry, etc.).

### 5.2.2 Identification of services

Based on the cost and revenue structures of current-day airports (see sections 4.2.4 and 4.2.5), the following high-level services that yield costs and revenues can be identified (most services are discussed in detail in section 5.2.3):

- Land provision (field)
- Passenger services (see 5.2.3.1)
    - Security check
    - Check-in
    - Passport control
    - Customs control
    - UM/ medical assistance
    - Ticketing
- ANSP (service+ infrastructure) (see 5.2.3.2)
    - Ground- and space-based navigation
    - Tower
    - Terminal Control Area
    - Information
- Terminal building (see 5.2.3.3)
    - Transit area/lounge
    - Baggage reconciliation area
    - Arrival and Departure halls
    - Intermodal connections
    - Boarding bridges
    - Check-in desks
    - Boarding gates
    - Security gates / checkpoints
    - Passport control areas
    - Customs control points
    - Information
    - Public services
    - Shopping / catering facilities
- Turnaround process (see 5.2.3.4)
    - De-icing

  - Boarding / de-boarding
  - Baggage loading / unloading
  - Chocks handling
  - Bridges / stairs handling
  - Buses
  - Fuelling
  - Catering replenishment
  - Aircraft cleaning
  - Sewage drain
  - Docking
  - Ground power for aircraft
- Communications (see 5.2.3.5)
  - Information (aircraft and staff)
  - Information (passenger)
- Runways (see 5.2.3.6)
- Cargo procedures (see 5.2.3.7)
- Lighting (airport) (see 5.2.3.8)
- Ground operations (see 5.2.3.9)
- Other services (see 5.2.3.10)

### 5.2.3 Brainstorm to evaluate existing and elicit new CE solutions for these services using Morphological Grid Analysis

Based on the above list of services an extensive brainstorming session was held on 22th March 2012 at Slot Consulting Ltd. Involving different experts from the aviation sector (airport handling experts, airline captains, air traffic controllers, economists, aircraft engineers and logistics consultants). Goal of this brainstorm was to evaluate, for each of the services distinguished, the current-day solutions used to perform these services. In addition, for each service new solutions were identified to resolve the bottlenecks in cost-effective current-day service provision. Note that the newly identified solutions listed below can be combined and do not necessarily substitute each other.

The following subsections are set up according to the order of current-day services listed above. ‘Land provision’ as a service is not discussed, because it was considered a basic element of any airport (current-day or future) and no alternative solution to providing land to support air transport seemed possible.

#### 5.2.3.1 Passenger services

The following passenger services are discussed below:

- Security check
- Check-in
- Passport control

- Customs control
- UM/ medical assistance
- Ticketing

**Security check**

The most likely solution for security check in 2050 is a combination of biometric identification and passenger screening. The whole territory of the terminal building will be covered by detectors which will identify any dangerous materials.

The current security procedure involves at least 4 person/ security line as follows:

- 1 person needed to help the passenger to place baggage and clothing on the belt.
- 1 person needed for screening of the items on the belt.
- 2 people (1 male/ 1 female) needed to check the passenger with hand-device in case of security alarm raised by the gate.

Using THz technology security lines will be unnecessary, since a limited number of operators can observe all the passengers in the terminal building, while a small team of security people will intervene in case of alarm situation. Depending on the airport size 5 to 50 lines are available per terminal that means 20-200 people/ shift resulting approx. 80-800 people. Using THz technology 3-10 operators and 4-8 security people/ shift will provide the service, which means 7-18 people/ shift, all together 28-72 people. The above numbers are based on the assumption that in the future the whole travel chain will be secured and the appearance of dangerous materials and goods will be minimal. The decrease of staff will be more intense on bigger airports.

Table 15: Security check procedures

| **Service/ Procedure** | **Parameters** | | | |
|---|---|---|---|---|
| | **Alternate solution** | **Positive effect** | **Negative effect** | **Feasibility (technological and economic)** |
| Security check | PAX classification (trusted passengers - no screening) | Faster procedure due not each PAX will be screened | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |
| | no check points, but terminal screening | Seamless PAX flow | Adequate technology needed | Technology not yet implemented |
| | biometric identification | Seamless PAX flow | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |
| | Face recognition | Seamless PAX flow | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |

**Check-in**

The current development shows that in the future the most widely distributed solution will be the usage of personal communication devices. In 2050 personal communication devices will automatically communicate and check-in with the appropriate devices at the airport, so there will be no need for dedicated check-in facilities. All the required information will be available via mobile communication such as identification, payment, gate number, terminal layout, route to gate etc. The passenger as automatically identified customer will receive all information that he/she needs as customer in a personalised format. (For example: not the floor plan of the terminal with the gates, but rather the location of the gate that she/he has to use and the direction to reach it.)

Table 16: Check-in procedures

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Check-in | Self-check-in | Seamless PAX flow | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |
| | Biometric identification | Seamless PAX flow | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |
| | Check-in by mobile/ smart phone | Seamless PAX flow | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |
| | Constant electronic identification | Seamless PAX flow | | Technologically feasible Economically feasible |

**Passport control**

With the widely applicable usage of the passport with biometric identifier the most likely solution in 2050 is biometric identification. Mobile communication could however provide some services in this field too as identification could be done through such device.

**Customs control procedure**

According to the current development directions, the custom control procedure will be done by biometric identification of passengers.

**UM/ medical assistance**

Unaccompanied children in the future will be helped by personal communication devices which will show the map of the airport and the direction to go to the appropriate gate basically providing indoors navigation.

Medical assistance for passengers with limited mobility could be provided by robots or self-moving wheel chairs. In urgent cases the human intervention could be required.

**Ticketing**

The currently existing ticketing offices will disappear in the future and will be completely substituted by on-line sales. The ticket won't be issued for a single flight or other phase of the journey, yet after the selection of the offered route consisting of several phases (using different transportation means) the transport chain will recognise the passenger as valid customer allowing to proceed seamlessly all the way to the end of the chain that is destination.

Table 17: The possible alternate solutions for Passenger procedures

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Passport control procedure | Biometric identification | Seamless PAX flow | Check point needed which can be a bottleneck | Technologically feasible Economically feasible |
| | Constant electronic identification | Seamless PAX flow | | Technologically feasible Economically feasible |
| Customs control procedure | There will be no custom | No check point | | Political feasibility can be questioned |
| UM/ medical assistance | On medium/ high density only | Less staff needed | | Technologically feasible Economically feasible |
| | Robot assistance | No staff needed | | Technologically feasible Economically feasible |
| Ticketing | On-line sales | Less staff needed (no ticket office) | | Technologically feasible Economically feasible |

#### 5.2.3.2 ANSP

The following Air Navigation Service Provisions are discussed below:

- Ground- and space-based navigation
- Tower

- Terminal Control Area
- Information

**Ground and space based navigation**

The evolution of navigation systems shows a shift towards satellite based navigation augmented system (directly (GBAS) or indirectly (SBAS)) from the ground where needed. Legacy ground based systems will serve as a backup. The spread of synthetic vision is also foreseen.

GNSS based navigation is already available and will be surely mature enough to be used for approach procedures in the future. However the precision of such systems standing alone (without augmentation) is not adequate for low visibility operations. It is operationally feasible on airports where low visibility operations are very rare, and traffic density is not high. In other cases some kind of precision enhancement is required.

SBAS is already available in many parts of the world (WAAS - USA, EGNOS – Europe etc.) and it could be operationally feasible providing higher precision than GNSS alone enabling nearly all-weather operations.

GBAS technology is available and can be tailored to local expectations if needed enabling high precision navigation in close vicinity of airports supporting all-weather operations. It could be a more expensive solution compared to SBAS as the funding of such a system might totally fall on the airport operator. Aircraft must be equipped to receive this signal.

The use of synthetic vision in the cockpit will surely enhance awareness of pilots, however it can be misleading in a mixed environment (in terms of aircraft equipage). Synthetic vision technology could enable less sophisticated and hence cheaper airport lighting, including those that are necessary for low visibility operations. The technology is rather expensive presently.

Table 18: The possible alternate solutions for Communication, Navigation and Surveillance systems

| SERVICE/ PROCEDURE | | PARAMETERS | | | |
|---|---|---|---|---|---|
| | | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Communication, Navigation and Surveillance systems | ILS | GNSS based approach | Cheap and globally available | Precision is not adequate for low visibility operations | Technology available and in use already, operationally feasible on airports |
| | MLS | Synthetic vision | Enhanced situational awareness in cockpit, terrain clearance | Could be misleading in mixed environment | Technology available, operationally feasible on airports |

| Service/ Procedure | | Parameters | | | |
|---|---|---|---|---|---|
| | | Alternate solution | Positive effect | Negative effect | Feasibility (technological and economic) |
| | PAPI | SBAS | Regionally available in many parts of the world, precision good for low visibility | Not everywhere available | Technology available, operationally feasible on airports |
| | VOR/ DME/ NDB | GBAS | Can be fitted to local needs | Local investment needed | Technology available, operationally feasible on airports |
| | Radar | Only primary radar | Intruders and non-cooperative targets can be detected | Operationally not essential | Expensive |
| | | ADS-B | Simple receiving capability needed from ground | Information and precision based on aircraft systems | Technology available, operationally feasible on airports |

**Tower**

Operating a small and medium density airport, a remote tower would be feasible. Communication and information distribution will take place via data-link. The feasibility of the level of automation will be decided on traffic density, but full operational SWIM capability is assumed. This will enable digital communication even in low density airports.

Table 19: The possible alternate solutions for the Tower

| Service/ Procedure | | Parameters | | | |
|---|---|---|---|---|---|
| | | Alternate solution | Positive effect | Nega-tive effect | Feasibility (technological and economic) |
| Tower | GND, TWR | Remote tower | Lower operating cost, especially for remote multiple towers | Losing visual backup | Technology available, operationally feasible on small airports |
| | Control | A-SMGCS | Conflict detection, auto routing | | Economically feasible only in medium to high traffic density |
| | Delivery | Digital clearance | Less workload | | Technology available, operationally feasible on airports |
| | | Trajectory clearance | More predictability | | Technology available, operationally feasible on airports |

**Terminal Control Area (TMA)**

The role of controllers in the TMA will change: as 4D trajectory management enables longer term clearances, the controller tasks will shift towards planning, and the voice communication will be reserved for non-standard situations. Higher automation is foreseen with less tactical intervention.

Table 20: The possible alternate solutions for the Terminal control area

| Service/ Procedure | | Parameters | | | |
|---|---|---|---|---|---|
| | | Alternate solution | Positive effect | Negative effect | Feasibility (technological and economic) |
| Terminal control area | Planning | 4D trajectory management, datalink | Less voice communication | | Technology available, operationally feasible on airports |
| | Executive | | | | |
| | TD | | | | |

**Information**

Information will be used in digital format only, the flip boards will become obsolete as the information will be available directly to whom it concerns when it is needed trough mobile communication. Full SWIM capability is assumed.

Table 21: The possible alternate solutions for the Information flow

| Service/ Procedure | | Parameters | | | |
|---|---|---|---|---|---|
| | | Alternate solution | Positive effect | Negative effect | Feasibility (technological and economic) |
| Information | ATIS | D-ATIS | | | Technology available, operationally feasible on airports |
| | AIS | | | | |
| | | e-AIS | | | Technology available, operationally feasible on airports |
| | | SWIM | | | Technology available, operationally feasible on airports |

### 5.2.3.3 Terminal building

The following services are discussed below related to the terminal building:

- Transit area/lounge
- Baggage reconciliation area
- Arrival and Departure halls
- Intermodal connections
- Boarding bridges
- Check-in desks

- Boarding gates
- Security gates / checkpoints
- Passport control areas
- Customs control points
- Information
- Public services
- Shopping / catering facilities

The layout of the airport terminals currently reflects the need for channelling passenger through several check points for sorting passengers. The first of such are the check-in area equipped with the check-in desks. Even today they become less and less used and in the future it will disappear.

Next such point is the security check with long routes for queue. As the security procedures and devices will be changed in a way they will cover large or full area of the terminals such artificially created bottlenecks won't be required anymore.

The passport control and customs for arriving passengers will become also obsolete together with the distinction between the Schengen and Non-Schengen flights.

The passengers will be identified upon arrival at the Terminal and at the same time screened from security point of view. Therefore the current layout of the terminals won't be required anymore.

The main goal of the layout will be to process as much passengers as possible within a given period of time. As the waiting time for passengers will be reduced, there won't be need for considerable commercial space too.

**Transit area/ lounge**

It seems that the transit area will not disappear from the airport of the future. However as the whole terminal area will be covered by the security and self-boarding and security coverage it will become smaller than today.

Table 22: The possible alternate solutions for the Transit area / lounge

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Transit area / lounge | - | - | - | - |

**Baggage reconciliation area**

For baggage transportation also intermodal connections will be applied. This means that the baggage not necessarily travels with the passenger, but on a different route using different transportation modes.

At the start and end point of the baggage intelligent transportation devices will sort the baggage and direct it to the appropriate place. In this way the baggage reconciliation area will be much smaller than today or even completely disappear and substituted with door-to-door transportation of the baggage.

Table 23: The possible alternate solutions for the Baggage reconciliation area

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Baggage reconciliation area | Door-to-door | Seamless flow | Security questions may arise | Technology available, operationally feasible |
| | | No check point needed | | |
| | Baggage will travel on different route | New type of aircraft (full PAX) allows transport of more PAX | Security questions may arise | Technology available, operationally feasible |
| | Intelligent baggage handling | Faster procedure | | Technology available, operationally may not feasible |

**Arrival and departure hall**

As the travel will be intermodal and door-to door the area of the arrival and departure hall at the airport will be reduced.

Table 24: The possible alternate solutions for the Arrival hall and Departure hall

| SERVICE/ PROCEDURE | ARRIVAL HALL | | | |
|---|---|---|---|---|
| | DEPARTURE HALL | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Arrival hall | Door-to-door travel | Smaller terminal building | Security questions may arise | Technology available, operationally feasible |
| Departure hall | Door-to-door travel | Smaller terminal building | Security questions may arise | Technology available, operationally feasible |

**Intermodal connections**

The airport will become an intermodal hub providing a wide variety of transportation modes, such as:

- Public transport
    - Metro, tram, bus
    - Train
    - Ship
- Private transport
    - Good access to highway, motorway will enable use of private cars
    - Parking facilities will support private car use

Table 25: The possible alternate solutions for the intermodal connections

| SERVICE/ PROCEDURE | | PARAMETERS | | | |
|---|---|---|---|---|---|
| | | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Intermodal connections | Railway | Fast trains connecting at the Terminal | Better connections by public transport | | Technology available, operationally feasible |
| | Ship | Where applicable connecting at the Terminal | Better connections by public transport | | Technology available, operationally feasible |
| | Public transport (metro, bus) | Connecting at the Terminal | Better connections by public transport | | Technology available, operationally feasible |
| | Road connection | Connecting at the Terminal | Better availability | | Technology available, operationally feasible |
| | Parking facilities (private cars) | The significance is much lower with the evolvement of public transport, but Short and long term parking as close as possible to the terminal | Less land required for parking lots | | Technology available, operationally feasible |

**Boarding bridges**

Depending on the future model of aircraft it may become unnecessary to provide this service. In case of short haul flights where the emphasis will be on required frequency the main concern will be the turnaround time. The time between flights might be as short as 15 minutes. To enable that it will require to achieve higher level of automation and simplification of the handling process. To reduce the number of servicing vehicles it is possible to integrate of servicing equipment partially into the stand itself and the rest of it to build into the aircraft using new lightweight materials. Also taking into consideration the simplified terminal structure it may become easier to let the passenger to walk strait to the aircraft which will be standing adjacent to the terminal. For long-haul flights the turnaround time is not such a pressing issue due to the long continuous flight time. However it may be appropriate to use considerably larger aircraft that would need additional equipment for boarding and less on-board equipment as that can be provided at both ends of the flight.

Table 26: The possible alternate solution for the jet way/bridge

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Jet way/ bridge | Self-serviced a/c | Faster procedure simplified building layout and less ground service equipment | | Technology available, operationally feasible |

**Check-in desks**

In the future check-in desk will disappear and substituted by self-check-in facilities due to the introduction of self-check-in and online check-in less and less passengers require this service. For the baggage check-in door-to-door baggage transportation and baggage drop-off points will be provided.

**Boarding gates**

In the future the boarding gate in the current form will disappear and be substituted by self-boarding facilities. Because of intermodality the boarding will happen at the first stop of the journey. The passengers will be identified by biometrical identification facilities.

Table 27: The possible alternate solutions for the boarding gate

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Boarding gate | Biometric identification | Secure and reliable procedure | Check point needed which might become bottleneck | Technologically feasible Economically feasible |
| | Self-boarding gate | Faster procedure, less staff needed | | Technologically feasible Economically feasible |

**Security gates / checkpoints**

As it was described before, the security gate will be substituted by a security area, which covers a large territory and allows faster security process.

Table 28: The possible alternate solutions for the security gate/ check points

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Security gate/ check points | Biometric identification | Secure and reliable procedure | Check point needed which might become bottleneck | Technologically feasible Economically feasible |
| | Classification of PAX | Division of PAX results faster procedure | Method of classification can be questioned | Technologically feasible Economically feasible |
| | On board security | No security check at the airport | May cause bottleneck upon boarding, Security questions may arise | Technologically feasible Economically feasible |

**Passport control areas**

If passport control will remain in the future the identity of passengers can be checked during the entrance into the terminal or boarding process by biometrical identification.

Table 29: The possible alternate solutions for the passport control

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Passport control | Biometric identification | Secure and reliable procedure | Check point needed which might become bottleneck | Technology available, operationally feasible |
| | Classification of PAX | Division of PAX results faster procedure | Method of classification can be questioned | Technologically feasible Economically feasible |

**Customs control points**

In the future it’s more likely that the custom control points will disappear (see Schengen in EU).

Table 30: The possible alternate solution for the customs control points

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Customs control points | Will disappear | Faster procedure | Politically can be questioned | Technologically feasible<br>Economically feasible |

**Information**

With the spread of advanced personal communication devices information related to a passenger can be personalized and send directly to the end user. Thus the current screens and information signs will disappear and substituted by personal communication devices which can collect all the information related to a flight (boarding pass, boarding time and gate, etc.) and show them on the screen. With the usage of GPS or similar solutions this device also can provide a map of the terminal building, the current position and show the way to the appropriate gate.

Table 31: The possible alternate solutions for the information

| SERVICE/ PROCEDURE | | PARAMETERS | | | |
|---|---|---|---|---|---|
| | | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Information | FIDS displays | Info will be send to personal communication device | Less energy usage because of lack of screens | | Technologically feasible<br>Economically feasible |
| | Automated docking guidance display | Info will be send to on board display | Less energy usage because of lack of screens | | Technologically feasible<br>Economically feasible |
| | Information signs | Info will be send to on board display | Less energy usage because of lack of screens | | Technologically feasible<br>Economically feasible |

**Public services**

Public services will be provided at the airport as today.

Table 32: The possible alternate solutions for the public services

| Service/ Procedure | | Parameters | | | |
|---|---|---|---|---|---|
| | | Alternate solution | Positive effect | Negative effect | Feasibility (technological and economic) |
| Public services | Air conditioning | Passive solutions | Energy usage can be reduced | | Technologically feasible<br>Economically feasible |
| | Waste removal | Recycling | Green solutions are appreciated by government and public also | | Technologically feasible<br>Economically feasible |
| | Lightening | Led | Energy usage can be reduced | | Technologically feasible<br>Economically feasible |
| | | Passenger movement activated | Energy usage can be reduced | | Technologically feasible<br>Economically feasible |
| | | FIPEL[21] | Energy usage can be reduced | | Technologically feasible<br>Economically feasible |
| | Rest rooms | - | - | - | - |

**Shopping/Catering facilities**

The Shopping and Catering facilities will be reduced. Because of the spread of on-line buying and the reduction of the time spent at the airport it's more likely that the Shopping facilities will completely disappear, while the catering facilities will be reduced to the minimum.

As the purpose of the terminal will be strictly to provide the required services that is to process as many passengers as possible for the convenience of passengers it is essential to do so as fast and simple as possible. However, as the terminal probably located at a transportation node and attracts lot of traffic it wouldn't be wise to let this possibility unutilized. Therefore the airport should take advantage of that fact and participate in obtaining of non-aviation related revenues.

Table 33: The possible alternate solution for the shopping/catering facilities

| Service/ Procedure | Parameters | | | |
|---|---|---|---|---|
| | Alternate solution | Positive effect | Negative effect | Feasibility (technological and economic) |
| Shopping/ Catering facilities | Minimum will be provided | Terminal building area can be reduced | | Technologically feasible<br>Economically feasible |

#### 5.2.3.4 Turnaround process

The following turnaround services/processes are discussed below:

- De-icing
- Boarding / de-boarding
- Baggage loading / unloading
- Chocks handling
- Bridges / stairs handling
- Buses
- Fuelling
- Catering replenishment
- Aircraft cleaning
- Sewage drain
- Docking
- Ground power for aircraft

**De-icing**

Thanks to the technological development smart materials will be used for the future aircraft making the pre-flight de-icing procedure less used or obsolete.

Table 34: The possible alternate solutions for the de-icing

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| De-icing | Depends on climate and traffic density | At warmer areas minimal de-icing will be provided | At colder areas de-icing will be still needed | n/a |
| | Dedicated stand near to the Holding Point | Apron occupation time is reduced to minimum | Holding Point could become a bottleneck | Technologically feasible<br>Economically feasible |
| | Heated leading edge | No de-icing needed | | Technologically feasibility can be questioned<br>Economically feasibility can be questioned |
| | Nano-technology based film on the leading edge | No de-icing needed | | Technologically feasibility can be questioned<br>Economically feasibility can be questioned |

**Boarding / disembarking**

A pioneering solution to speed up the boarding and de-boarding is the usage of cabin pods where the passengers can be seated before the arrival of the aircraft to the stand. (1) Other solution is the usage of multiple doors which also speeds up the boarding and disembarking procedure.

With the spread of self-boarding (which will happen on-board) the procedure will speed up, saving amongst other things staff costs.

Table 35: The possible alternate solutions for the boarding/de-boarding

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Boarding / deboarding | PAX into container | De-/Boarding time can be reduced | Technological problems may arise | Technologically may not feasible Economically feasible |
| | A/C supported | De-/Boarding time can be reduced | Technological problems may arise | Technologically may not feasible Economically feasible |

**Loading / unloading (baggage, mail or cargo)**

As long as any baggage, mail or cargo loading or unloading procedure will be applicable, such items very likely will be transported independently. The baggage can be dropped off well before the passenger departure time and can travel by train in case of short-haul flights or separated cargo airplane in case of long-haul flights.

The baggage, mail and cargo will be loaded into standardized containers suitable for all transportation modes making obsolete the re-loading of the items in case of transportation mode change (e.g. from train to aircraft). This will strengthen intermodal connections and speed up transportation.

The cargo hold of the aircraft will be adjusted to the new container types and the loading and unloading of the aircraft will be automated in the future.

Table 36: The possible alternate solutions for the loading/unloading

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Loading / unloading | Robots | Un-/Loading time can be reduced | | Technologically may not feasible Economically feasible |
| | Self-moving container | Un-/Loading time can be reduced | | Technologically may not feasible Economically feasible |

| | | | | |
|---|---|---|---|---|
| | Baggage will travel independently from passengers | Faster turnaround procedure | Difference in arriving times may occur | Technologically may not feasible<br>Economically feasible |

**Chocks on/ out**

The requirements towards this service will be highly dependable on the future aircraft types and novel solutions. Most probably short haul flights will be accomplished with relatively smaller aircraft with many self-servicing solutions to speed up the turnaround process; however aircrafts used for long haul flights will stay longer on the ground due to the higher amount of passengers to board and disembark. Therefore the weight reduction of such aircraft will have priority against the speed of the process, so in this case no on board solutions will be implemented and the service will remain.

**Bridge/ stairs**

The requirements towards this service will be highly dependable on future aircraft types. Most probably the short haul flights will be accomplished with relatively smaller aircraft with many self-servicing solutions including means that allows passengers to embark and disembark without additional equipment; however aircrafts used for long haul flights due to their bigger dimensions might need additional ground equipment to help passengers to embark and disembark.

Table 37: The possible alternate solution for the bridge/stairs

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Bridge / Stairs | Underground tunnels | Easier manoeuvring on ground (aircraft and ground vehicles) | | Technologically feasible<br>Economically feasible |

**Bus (boarding/ de-boarding)**

Due to the layout of the terminal most of the stands will be near to the terminal building enabling the passengers to reach the aircraft with a short walk.

Table 38: The possible alternate solution for the bus (boarding/ disembarking)

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Bus (boarding/ disembarking) | Underground tunnels | Easier manoeuvring on ground (aircraft and ground vehicles) | | Technologically feasible Economically feasible |
| | No bus needed due to the layout of the terminal | Faster turnaround procedure | | Technologically feasible Economically feasible |

**Fuelling**

Fuelling pipes will be available at every stand providing immediate access to the fuel upon arrival. This solution enables the fuelling of the aircraft through multiple pipes using both wings.

Table 39: The possible alternate solution for the fuelling

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Fuelling | Dedicated, auto fuelling at Holding points | Apron occupation time is reduced to minimum | | Technologically feasible Economically feasible |
| | Fuelling pipes | Faster fuelling No need for fuel trucks | | Technologically feasible Economically feasible |

**Catering replenishment**

Only the long-haul flights will take catering, as the travel time from door-to-door in case of short-haul flights will be quiet short (around 1,5 hour on average in Europe).

The catering replenishment of long-haul flights will be as much automated as possible.

Table 40: The possible alternate solution for the catering replenishment

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Catering replenishment | Automated | Less staff needed | | Technologically feasible<br>Economically feasible |
| | No catering | More space for PAX on a/c deck | | Technologically feasible<br>Economically feasible |

**Aircraft cleaning**

The cleaning of the aircraft will be done by automatic vacuum cleaners which can start their work during boarding or disembarking of the passenger thus saving time. The usage of intelligent materials on the surfaces of cabin bathrooms or seats and carpets will make cleaning needless as these materials will be self-cleaning and self-repairing. (1)

Table 41: Possible alternative solutions for the aircraft cleaning

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Aircraft cleaning | By robots (self-moving vacuum cleaner) | Cleaning time is reduced as it can be done during de-/boarding | | Technologically feasible<br>Economically feasible |

**Deflation of waste water and replenishment of potable water**

The underground pipe systems will help the deflation of waste water and replenishment of potable water. The waste water will be treated by reverse osmosis.

Table 42: Possible alternatives for the deflation of waste water and replenishment of potable water

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Deflation of waste water | On board water cleaning | | Requires extra equipment on board | Technologically feasible Economically feasible |
| | Automated system for recycling | | Requires extra equipment on board | Technologically feasible Economically feasible |
| Replenishment of potable water | On board water cleaning | | Requires extra equipment on board | Technologically feasible Economically feasible |
| | Automated system for recycling | | | Technologically feasible Economically feasible |

**Docking in/out**

Self-taxi using electric motors in the undercarriage will replace today's aircraft tugs reducing the time needed for docking.

Table 43: The possible alternate solution for the docking in/out

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Docking in/out | Electric wheel | No pushback needed | Requires extra battery on board | Technologically feasible Economically feasible |

**Ground Power Unit**

The auxiliary power supply will be provided through a built-in electrical network available at each stand.

Table 44: The possible alternate solution for the GPU

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| GPU | Built in network at stands | No extra equipment needed | | Technologically feasible Economically feasible |

#### 5.2.3.5 Communication

The following communication services are discussed below:

- Information (aircraft and staff)
- Information (passenger)

To start, the table below summarizes the communication services provided by airports nowadays and possible alternatives:

Table 45: The communication services and their possible alternate

| SERVICE/ PROCEDURE | | PARAMETERS | | | |
|---|---|---|---|---|---|
| | | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Information (Aircraft) | Weather observation | Automated<br>SWIM<br>Smart applications | Accurate, up to date information | | Technologically feasible Economically feasible |
| | Weather information provision | Smart applications<br>SWIM | Accurate, up to date information | | Technologically feasible Economically feasible |
| | Flight office | Smart applications<br>SWIM<br>Web based | Accurate, up to date information | | Technologically feasible Economically feasible |
| | ACARS | All communication by CPDLC<br>SWIM | Accurate, up to date information | | Technologically feasible Economically feasible |
| Information (Staff) | FIDS | SWIM | Accurate, up to date information | | Technologically feasible Economically feasible |
| | AFTN | SWIM | Accurate, up to date information | | Technologically feasible Economically feasible |
| | SITA | SWIM | Accurate, up to date information | | Technologically feasible Economically feasible |
| | CCR | | | | |
| | Radio communication | | | | |
| Information | PA | Smart device | Accurate, up | | Technologically |

| SERVICE/ PROCEDURE | | PARAMETERS | | | |
|---|---|---|---|---|---|
| | | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| (PAX) | FIDS | Smart device | to date information | | feasible<br>Economically feasible |

**Information (aircraft and staff)**

SWIM will provide end-users with early availability of the most accurate information on weather situation, air congestion, situation on the ground, etc. resulting better situational awareness.

**Information (passengers)**

All information for passengers in regard to their flight (gate change, boarding time, etc.) will be sent to their smart device (smart phone, tablet, etc.). This way there will be no need for information screens saving resources.

#### 5.2.3.6 Runways

The following table summarizes two concept solutions related to airside operations and infrastructure:

Table 46: The areas related to aircraft operations

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| RWY | Magnetic runway | Less noise, COx, NOx, etc emission | Complicated configuration | Technologically (yet) not feasible<br>Economically not feasible |
| | Circular RWY | Short taxiways<br>Queuing can be rescued | Complicated configuration | Diversion of existing RWYs and TWYs may not be feasible economically |
| TWY | - | - | - | - |
| Apron | - | - | - | - |

Given the technological and economic challenges of both solutions, it seems justified to conclude that the future operation area will look mostly the same as today as there is no feasible alternative foreseen.

Since the layout of the terminal will change it will affect the apron as well though. Several systems (e.g. fuelling, electricity) will be built in the stands themselves (see above).

#### 5.2.3.7 Cargo procedures

The cargo related services are summarized in the next table:

Table 47: The cargo related services

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Security check | Flow is not starting at the airport | Warehouse at airport can be Smaller<br>Faster procedures | | Technologically feasible Economically feasible |
| Custom procedure | Flow is not starting at the airport | Faster procedures | | Technologically feasible Economically feasible |
| | No custom | Faster procedures | | Technologically feasible Economically feasible |
| Sorting | Flow is not starting at the airport | Faster procedures | | Technologically feasible Economically feasible |
| | NFC | Faster procedures | | Technologically feasible Economically feasible |
| | Automatic disposed | Faster procedures | More equipment needed for sorting | Technologically feasible Economically feasible |
| Dangerous goods related procedures | Flow is not starting at the airport | Faster procedures | Security questions may arise | Technologically feasible Economically feasible |

The flow of the cargo will change in the future: the airport will be only one element of the transportation chain; cargo will travel in the same intermodal container during the whole journey. Therefore the shipment will be screened and sorted on the first stop of the chain, making the security check and sorting unnecessary at the airport (typically an intermediate node in the chain). Regarding paper based procedures, such as procedures in case of dangerous goods or custom, e-freight solutions will replace them.

#### 5.2.3.8 Lighting (Airport)

Although airport lighting has been left quite unchanged for several years, new lighting technologies evolved e.g. by the development of cost-effective LED and FIPEL light sources. A considerable amount of cost reduction could be implemented by retrofitting in this field.

Table 48: Lighting (Airport)

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Runways | Synthetic vision in cockpit | Reduced costs | | Technologically and economically feasible |
| Taxiways | Led | Reduced costs | | Technologically and economically feasible |
| | FIPEL | Reduced costs | | Technologically and economically feasible |
| Apron | Led | Reduced costs | | Technologically and economically feasible |
| | FIPEL | Reduced costs | | Technologically and economically feasible |
| Terminal building | Led | Reduced costs | | Technologically and economically feasible |
| | FIPEL | Reduced costs | | Technologically and economically feasible |

The lighting at the airport will be facilitated by led light thus reducing the electricity usage and cost. On the runways and taxiways the lighting might be partly replaced by the usage of synthetic vision on board of the aircrafts. The remaining lights can be equipped with sensors switching the light on and off as needed.

#### 5.2.3.9 Ground operations

The following ground operation solutions have been identified:

Table 49: Ground operations

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Apron /runway/ taxiway control (DAM) | Sensors | Less, and/or better distributed human workload | Extra maintenance | Technologically feasible<br>Economically feasible |
| | Automatic FOD detection | Less, and/or better distributed human workload | Extra maintenance | Technologically feasible, Quality of Service is in question<br>Economically feasible |
| Marshalling | Virtual cockpit<br>Smart a/c | Ultimate substitute for marshalling | More complex A/C systems | Technologically feasible<br>Economically feasible (extensive authorization costs) |
| Snow removal | Automatized | Less, and/or better distributed human workload | Extra maintenance | Technologically feasible<br>Economically feasible |

#### 5.2.3.10 Other services

The following additional service improvements have been identified:

Table 50: Other services

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| Aircraft hangars (maintenance) | Pre-flight check supported by a/c systems | Less, and/or better distributed human workload | Extra maintenance | Technologically feasible<br>Economically feasible |
| Fire fighting | Combined with | Cost- | Increasing | Technologically feasible |

| SERVICE/ PROCEDURE | PARAMETERS | | | |
|---|---|---|---|---|
| | ALTERNATE SOLUTION | POSITIVE EFFECT | NEGATIVE EFFECT | FEASIBILITY (TECHNOLOGICAL AND ECONOMIC) |
| | surrounding town | effective labour and equipment distribution | on-site times, risks | Economically feasible |
| Emergency control centre | (no alternate solutions foreseen) | - | - | - |

Note that during the brainstorm these procedures were expected to remain largely the same strongly - depending on local and international regulations.

## 5.3 Cost-Effective concept solutions

In this section, first all CE solutions developed in section 5.2.3 above are grouped in four categories. Next, all solutions in each group are further elaborated. Finally, each group of solutions is added to the service-less airport.

The concept solutions are grouped in the following way:

1. Intermodal SWIM: the basis for appliance of future solutions
2. ATM related solutions: ideas to reduce airport related navigational costs
3. Turnaround related solutions: ideas to reduce aircraft turnaround, baggage and passenger flow related processes and services
4. Terminal related: ideas to reduce terminal building related airport costs

Below, each individual concept solution is detailed.

### 5.3.1 Intermodal SWIM

**Purpose:**

To connect the information system of different transportation modes and enable up-to-date data sharing.

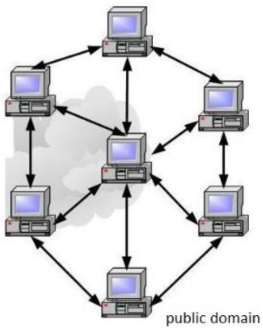



Figure 13: The Intermodal SWIM Concept Schematics

**Detailed description:**

System Wide Information Management (SWIM) is an advanced technology program designed to facilitate greater sharing of Air Traffic Management (ATM) system information, such as airport operational status, weather information, flight data, status of special use airspace, and National Airspace System (NAS) restrictions. In the future it will be extended to all transportation modes.

All future solutions will be based on communication and information sharing and strongly supported by ICT.

To support the convenience of the passengers and provide full intermodality enormous amount sof information needed to be processed. Furthermore this information needed to be available to the passenger during the whole journey and the system needs to receive information about the movement of the passenger.

The basis of this system would be Intermodal SWIM, which would enable to each transportation mode and the passengers to be connected all the time.

**Foreseen benefits:**

From the passenger's perspective the main benefit will be that travellers will receive up-to-date information automatically in regard to the different stops of their journey, such as arrival and departure times, possible delays, connection times, etc. Transportation companies will have more information about the status and place of the passenger and also about possible delays caused by other transportation modes.

### 5.3.2 ATM related solutions

#### 5.3.2.1 SBAS/ GBAS

**Purpose:**

Enable more precise all-weather navigation and increase safety by increasing the situational awareness of the pilots while decreasing the workload of the ANSP staff.

**Detailed description:**

The evolution of navigation systems shows a shift towards satellite based navigation augmented system (directly (GBAS) or indirectly (SBAS)) from the ground where needed. Legacy ground based systems will serve as a backup. The spread of synthetic vision is also foreseen.

GNSS based navigation is already available and will be surely mature enough to be used for approach procedures in the future. However the precision of such systems standing alone (without augmentation) is not adequate for low visibility operations. It is operationally feasible on airports where low visibility operations are very rare, and traffic density is not high. In other cases some kind of precision enhancement is required.

SBAS is already available in many parts of the world (WAAS - USA, EGNOS – Europe etc.) and it could be operationally feasible providing higher precision than GNSS alone enabling nearly all-weather operations.

GBAS technology is available and can be tailored to local expectations if needed enabling high precision navigation in close vicinity of airports supporting all-weather operations. It could be a more expensive solution compared to SBAS as the funding of such a system might totally fall on the airport operator. Aircraft must be equipped to receive this signal.

**Foreseen benefits:**

Better all-weather operations increasing the airport capacity in adverse conditions; increasing safety by increasing situational awareness of the pilots and decreasing workload of the ANSP staff.

**Future benefits:**

Self-navigating aircraft.

#### 5.3.2.2 Synthetic vision in cockpit

**Purpose:**

To increase situational awareness and to provide pilot a clear view about the flying environment independently from the weather or from the time of the day.

**Detailed description:**

A Synthetic Vision System (SVS) is a computer-mediated system that provides a 3D picture of the environment. Originally it was developed by the NASA and the U.S. Air Force around 1980 when recognizing the need to improve pilot's situational awareness. It uses terrain, obstacle, geopolitical, hydrological or other databases stored on board of the aircraft, an image generator computer and a display. In addition it uses a GPD and an inertial reference system for navigation purposes.

**Foreseen benefits:**

This solution helps the pilots by increasing their situational awareness by providing a good quality picture of the aircraft's environment. From the airport side it reduces costs, because there will be no need for indication of taxy ways, stands, etc.

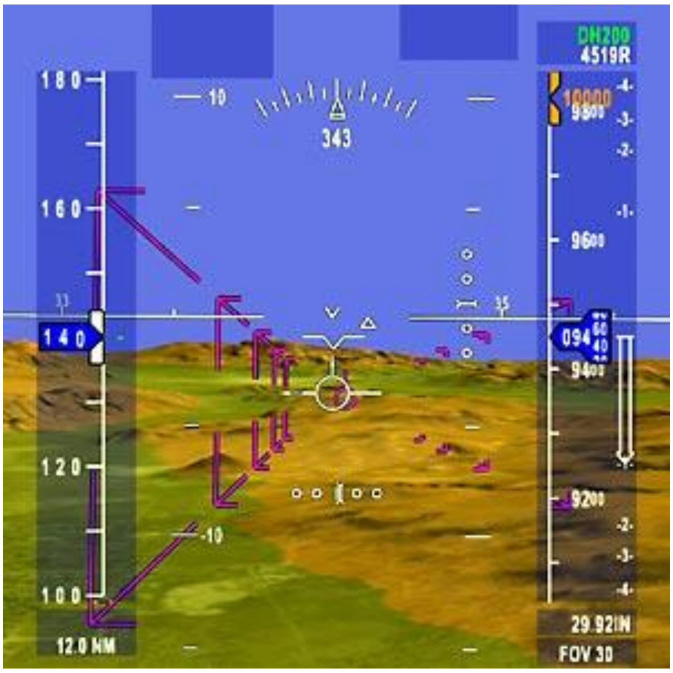



Figure 14: Example of a Synthetic Vision display

**Future benefits:**

Remote control, pilotless operation.

#### 5.3.2.3 D-ATIS

**Purpose:**

D-ATIS is a text-based, digitally transmitted version of the ATIS audio broadcast. It is accessed via a data link service such as the Aircraft Communications Addressing and Reporting System and displayed on an electronic display in the aircraft. The D-ATIS is incorporated on the aircraft as part of systems such as an EFB or an FMS.

**Detailed description:**

D-ATIS replaces the current voice based communication with automatic, digitally transferred information. This way it reduces costs, as less staff and equipment is needed and increases revenues due to more, digitally available, up-to-date information.

#### 5.3.2.4 4D trajectory

**Purpose:**

The concept relies on a reference business trajectory (RBT) which the airspace user agrees to fly and the service provider agrees to facilitate (subject to separation provision). It implies a target time of arrival over a waypoint of the trajectory, e.g. the initial approach fix (IAF), within a time window tolerance.

This feature will be available everywhere in the coming years as envisioned in SESAR.

**Detailed description:**

4D trajectory management enables longer term clearances, the controller tasks will shift towards planning, and the voice communication will be reserved for non-standard situations. Higher automation is foreseen with less tactical intervention.

**Foreseen benefits:**

From an ANSP point of view the application of 4D trajectory operations will cause a reduction in workload compared to today. Given the aforementioned shift from tactical to strategic planning, a reduction in ANSP fees can be foreseen. Airlines will primarily benefit from this; airports, however, may also benefit via an increase in passengers attracted by resulting lower air fares.

#### 5.3.2.5 Remote tower

**Purpose:**

In areas with more than one airport depending on the traffic and weather circumstances the air navigation services can be provided by one, remote tower that covers several airfields and different airspace. In this case obviously the related staff costs would decrease drastically.

**Detailed description:**

Remote Tower concept relies on the possibility providing total situational awareness regarding the air/ground traffic around a specific airfield to an air traffic controller staff that is not necessarily on site, by means of remote sensing techniques, such as radar, ADS-B, SWIM, etc. Detaching the ATC from the airfield physically would enable sharing tower control resources among more than one airport.

**Foreseen benefits:**

Benefits are depend on the area served by the new remote tower. The small airports could be substituted by 100%, while the medium or big airports would require almost the same staff number.

#### 5.3.2.6 On-board self-boarding gate

**Purpose:**

The ‘boarding gate’ will be on board of the aircraft, the passengers will be required to identify themselves while entering the aircraft. The identification will be done by biometric devices.

**Detailed description:**

Biometrics will enable quick identification, preferably without the need for the passenger to even stop walking. This, together with the elimination of traditional boarding passes will open the possibility of commence the boarding “on-the-go”, without extensive queues in the jetways.

**Foreseen benefits:**

This solution substitutes the airport based boarding gate and related staff, this way reducing costs. Furthermore it eliminates a checkpoint and the queue in front of it making the turnaround process faster.

### 5.3.3 Turnaround related

#### 5.3.3.1 Self-cleaning materials

**Purpose:**

Self-cleaning materials require less work power (and thus less staff costs) for cleaning aircraft and airport terminals leading to a positive cost effect on aviation and non-aviation related costs.

**Detailed description:**

Nature has already developed an elegant approach that combines chemistry and physics to create super repellent surfaces as well as self-cleaning surfaces. Lotus leaves is the best example of self-cleaning surfaces. The concept of self-cleaning textiles is based on the lotus plant whose leaves are well-known for their ability to self-clean by repelling water and dirt. More recently, botany and nanotechnology have united to explore not only the beauty and cleanliness of the leaf, but also its lack of contamination and bacteria, despite its dwelling in dirty ponds.

Basically, the lotus leaf has two levels of structure affecting this behaviour micro-scale bumps and nano-scale hair-like structures coupled with the leaf’s waxy chemical composition. On the basis of lotus leaf concept scientists developed a new concept called self-cleaning textile: the textile surface which can be cleaned itself without using any laundering action.

**Foreseen benefits:**

As the self-cleaning materials require less chemicals to be applied for cleaning and results less waste water to be handled it has a positive effect on sustainability. Mobility is positively affected by the shorter or none cleaning time.

#### 5.3.3.2 Door-to-door transportation of baggage

**Purpose:**

In the future check-in desk will disappear and substituted by self-check-in facilities due to the introduction of self-check-in and online check-in less and less passengers require this service. For the baggage check-in door-to-door baggage transportation and baggage drop-off points will be provided.

**Detailed description:**

There is a foreseen possibility to dispatch the passengers' baggage via separate routing while still being able to present it to the passenger by the time he/she gets to his/her destination. This would eliminate or share the extensive baggage handling activities of the airports.

**Foreseen benefits:**

Door-to-door transportation of baggage independently from the passenger enables a better utilization of aircraft baggage capacity and increases the level of service. In addition, the baggage flow at the airport will be more predictable and smooth.

Door-to-door transportation of baggage may cause extra costs for airport, however, since it requires additional staff and vehicles for the collection and distribution of the luggage. On the other hand, it offers a new service and provides more money on the revenue side. Furthermore, by collecting the luggage days(s) before departure it is possible to better plan the baggage loading of aircraft.

#### 5.3.3.3 Check-in using smart devices

**Purpose:**

The purpose of check-in using smart devices is to avoid the bottlenecks and queues at check points and provide a seamless journey experience to the passenger. Such solutions will save not only time but money as well, as time is money for passengers so an airport with a better throughput can set higher prices and reduce its operational cost.

**Detailed description:**

Check-in will take place at any point or all consecutive points of the journey and will not require any check-in desks with check-in agents. It will be done by personal communication devices linking to the IT system of the particular transportation node that automatically detects the passenger and performs the check-in.

**Foreseen benefits:**

The benefits are that the automated systems reduce the required staff end equipment needed for check points. Eliminating the physical checkpoints provides the passenger a simple walk through procedures improving not only the passenger procedure, but also shortening the turnaround time. As the system provides information for the passengers it also provides information on the passenger flow.

#### 5.3.3.4 Multiple, underground pipe system

**Purpose:**

An underground pipe system eliminates the need for fuelling trucks.

**Detailed description:**

By using underground pipe system, there is no need for fuelling truck, because the fuelling connection will be available at each stand. By using more pipes the process can be speeded up shortening the turnaround time. This solution reduces the Aeronautical costs because fewer vehicles are needed and the speed up of the turnaround enables better usage of the stands.

The underground pipe system can be used not only for fuelling, but also for provision of drinking water and removal of waste water. Using pipe systems, which are available at each stand, there is no need to wait for servicing vehicles, so the turnaround time can be shortened. The shorten turnaround results in a better utilization of airport stands.

**Foreseen benefits:**

This solution provides benefit also for sustainability, because the substitution of vehicles leads to less emissions. It also has a positive effect on mobility, because the usage of underground pipes reduces the turnaround time and eliminates the need for staff operating the handling vehicles and the time needed for positioning the vehicle. It also solves the problem of knock-on delays: when a vehicle has a delay at one handled aircraft and cannot be repositioned to serve the next one.

#### 5.3.3.5 Self-servicing solutions for aircraft

**Purpose:**

Short-haul planes will carry around 160-180 passengers. As the main goal of such aircraft will be to minimize as much as possible the time spent on ground, they will be equipped with automated self-servicing equipment such as boarding/ de-boarding facilities. They will not carry catering equipment, as the travel time will be at a minimum.

**Detailed description:**

Aircraft will be equipped with all the tools/equipment needed for an efficient turnaround, making the carrier more independent from the airport’s resources.

**Foreseen benefits:**

Reducing the number of vehicles needed for aircraft servicing may shorten the turnaround time, since there is no need to share the vehicle with other aircraft in the same time and there is no need to wait for its services. To this end, aircraft can be equipped with self-servicing facilities. As these activities are provided by the aircraft itself, the airport will not need to handle a vehicle park for the same reason, eliminating related costs. At the same time the turnaround time can be shortened, allowing more aircraft to be served in the same time period, thus increasing throughput.

This solution provides benefit also for sustainability, because the substitution of vehicles leads to less emissions. From the perspective of mobility it also has a positive effect, because it reduces the turnaround time.

#### 5.3.3.6 Taxiing and pushback with electric motors

**Purpose:**

The aircraft will be capable to perform ground movement using either ground equipment provided by the airport in the form of electric robot tugs or using on-board equipment. The goal of electric propulsion is to reduce emissions and fuel consumption.

**Detailed description:**

It is foreseen that ground taxiing will be powered by an electric motor driving the nose-wheels of the aircraft, instead of using the thrust of the main engines that are, while taxiing, operating in circumstances far from optimal (low RPM, relatively high noise and fuel consumption).

**Foreseen benefits:**

The benefit of this is that it will speed up the turnaround while in the same time reduce emissions and fuel consumption. It eliminates the waiting period related to the repositioning of the towing equipment yielding costly delays.

#### 5.3.3.7 THz based passenger screening

**Purpose:**

In the case of THz based passenger screening the whole territory of the terminal is covered by devices which are able to detect any dangerous materials or potential weapons. The technology makes the currently applied security procedures obsolete and increases security.

**Detailed description:**

Terahertz technology, and the coupled IT intelligence will be capable of scanning the passengers and their belongings while walking through the public spaces in the terminal, raising the security personnel's attention on potentially dangerous objects carried or suspicious behaviour with a sufficient reliability (low false alarm rate), leaving the other passengers free of time-consuming security checks.

**Foreseen benefits:**

The aeronautical costs will decrease, because there will be no need to use security gates. The aeronautical revenues will increase, because the throughput will be much higher. The non-aeronautical revenues will also increase, because the passengers will spend more time in the commercial area knowing that security check doesn't require any extra time.

#### 5.3.3.8 Biometric identification of passengers

**Purpose:**

Biometric identification of passengers in order to replace current-day check-in and identification processes to speed up these processes and improve passenger experience.

**Detailed description:**

Biometric identification of passengers can happen at several points of the journey: upon take off the bus, upon arrival to the airport terminal and so on. It can substitute for example check-in, if upon entering the airport terminal the automatic passenger identification recognises the passenger and performs check-in.

Biometric identification makes obsolete the transposal of identification through paper based means like ID card. As the technology evolves it becomes more available and affordable resulting wide application of needed equipment. Identification based upon the biometric characteristic of a person makes the creation and use of other means unnecessary therefore the falsification of identification document or accidental loss of it also become meaningless.

**Foreseen benefits:**

The person or passenger is recognised based on unique biometric characteristics. With the application of new technologies the process can be automated reducing staff needs and time required while boosting security.

### 5.3.4 Terminal related

#### 5.3.4.1 Active building technology

**Purpose:**

Active building technology (like aerogel) provides highly isolated buildings making the heating and cooling costs lower or minimal.

**Detailed description:**

Active building technology is capable to utilise solar and wind energy available through solar panels, paints containing spry-on solar-power cells. Another option is the use of nanotechnology providing electricity practically from any surface covered by it; this technology can transform solar energy to electric energy or apply fibre nets to conduct sunlight into the building during the daylight hours.

**Foreseen benefits:**

Active building technology, which takes into account also the environmental possibilities of the location, can help the reduction of the Non-aeronautical costs, such as heating, lighting and energy.

In regards to sustainability its positive effect is obvious: temperature control (both heating and cooling) needs less energy, artificial lighting is only required a few hours a day.

#### 5.3.4.2 Usage of state of the art lighting

**Purpose:**

Novel light-emitting technologies reduce costs by means of more efficient production of light beams.

**Detailed description:**

Field-induced polymer electroluminescent (FIPEL) lighting technology silently gives off a soft, white glow, without the annoying hum and yellow tint of fluorescent bulbs or the sharp, bluish hue of LED light fixtures. Hybrid lighting systems can provide natural light inside buildings during the day by using fibre optic cable bundles to channel the sunlight into the buildings. During the day the net of cheap fibre optic (material of these is plastic so the sunlight should be filtered to sort out harmful for plastic material elements) networks are conducting the daylight from outside the building into the areas located furthest away from the windows.

**Foreseen benefits:**

These technologies provide solutions that are highly energy saving and have a positive effect on human wellbeing (according to some studies the effects of daylight on the human behaviour and efficiency is highly positive). In addition, the need for electrical supply of the building is considerably lower or – during some periods of the day - none.

## 5.4 Summary of the advanced Cost-Effective airport concept

In this final section of Chapter 5, the overall cost-effectiveness of the integrated set of solutions listed in section 5.3 is investigated. To this end, first (5.4.1) an integrated story is offered describing the Cost-Effective airport by means of a door-to-door description of a journey in 2050. Next, the most important elements of the Cost-Effective airport are summarized, distinguishing between concept solutions focusing on improved service provision (5.4.2), an improved airport layout (5.4.3), an improved terminal layout (5.4.4), and improved turnaround process (5.4.5).

### 5.4.1 Integrated story of a Cost-Effective door-to-door journey

To start, let us imagine that we are in 2050 and that we would like to travel from Budapest to Frankfurt. Using our tablet we visit an internet travel site and enter the origin and destination location and the date when we would like to travel. The application offers different opportunities including door-to-door travel times, e.g.:

- We can go by airplane: taking 1,5 hour
- We may travel by train: taking 3 hours
- It is possible to go by bus: taking 8 hours

The application also introduces the travel fees, taking into account the travel time and cost. Assume we then choose the airplane as a means to travel. We could then subsequently choose two different options for baggage drop off:

- For an extra fee we can choose door-to-door delivery, where a van picks up our baggage at home and we receive it upon arrival at the destination place, weather is it the airport, a hotel, or a baggage pick-up point in the city centre.
- Alternatively, we can drop off the baggage at the airport terminal using a self-boarding service.

Assume we choose door-to-door delivery and we buy a ticket for the whole journey, including train (to and from the airport) and airplane with exact seat position. We receive a confirmatory message, which contains also information on train and flight departure, travel time for the sequences, seating numbers and baggage pick-up.

On the day of the flight the baggage pick-up van comes to get our baggage in the morning and later on we get on the train to go to the airport. The train station is also secured, as part of a secured transportation chain. No ticket is needed for travelling as we receive a QR code for our mobile which replaces it.

The airport terminal is part of a complex transportation centre point, where different public and private transportation possibilities are available, such as private car, private airplane, train, bus or taxi. We arrive well in time to the transportation centre, e.g. 25 minutes before the departure of the airplane, so we have enough time to eat a sandwich and drink a coffee and to download a book or magazine to the tablet for our journey. As the transportation centre is part of a bigger commercial terminal, to find a good restaurant or coffee bar doesn't mean a problem. While sitting in the coffee bar we receive a warning from our mobile device that the boarding will start in 10 minutes, so we need to proceed to the terminal.

The airport terminal is a separate part of the transportation centre. When we enter the terminal the following processes start automatically:

- Biometric identification
    - If the biometric identification fails (no information in the system about the particular passenger), the system automatically directs me to the 'Identification Check point', where our ID will be established and uploaded to the system
- Our mobile device automatically links to the terminal's IT system
    - Communication with the system will establish that we have a ticket for a particular flight,
    - The system will provide information regarding the number of the boarding gate and the map of the airport terminal,
    - A smart application on the tablet or smart phone can localize our position and using the received map can navigate us to the required boarding gate calculating also the required time to reach it.
- The THz based security system of the terminal will check if we have any dangerous materials or weapon on us.

The most important goal for the short-haul flight aircraft is to accomplish as many flights a day as possible. Therefore they are equipped with many built-in systems, such as boarding stairs, automated water replenishment, etc. to speed up the turnaround. In this case there is no catering at the aircraft, because a flight will not take more than 2 hours.

In case of the long-haul flights it is the opposite: the focus is on the comfort of passengers. The airplanes are much bigger, therefore requiring different handling equipment, for example special equipment to reach high level decks for boarding.

As our flight flies within Europe (short-haul), we go on the stairs of the aircraft and enter the deck. Upon entering the aircraft, the automated boarding process takes place, as the plane checks our identity using biometric identification system and the validity of ticket by connecting to our mobile device. We proceed to our pre-selected seat and in some minutes start the journey.

Upon arrival to Frankfurt airport, we leave the terminal and proceed straight to the train. There is no problem to find it, as our mobile device is in connection with the local IT system of the terminal and therefore receives personalized information regarding our further route.

We take the train and soon arrive to the hotel where we receive our baggage at the reception desk.

### 5.4.2 Improved service provision

In the future the following services will change as a result of the Cost-Effective improvements to airport processes and infrastructure sketched in section 5.3:

- Current passenger related procedures will disappear and fuse with the processes of other transportation mode.
- The ANSP's role will change and will be more limited in the future due to the automation of different procedures and the development of the GPS based navigation and self-separation.
- Runway and taxiway navigation (ILS, PAPI, etc.) and lightening equipment will change due to new aircraft equipment like synthetic vision and enhanced self-separation and navigation capabilities.
- Terminal buildings will fuse with service buildings of other transportation modes creating public intermodal transportation nodes.
- Turnaround processes will be more automated and some of the processes will completely disappear (e.g. current form of check-in or security check).
- Current communication technology will be substituted by smart devices (for passengers and staff) and SWIM based applications (aircraft and staff). The huge public displays will disappear yet every passenger will receive personalized information.

### 5.4.3 Airport layout

The CE solutions outlined in section 5.3 also impact the airport layout. The following figure represents the new airport layout that will accommodate all new solutions:

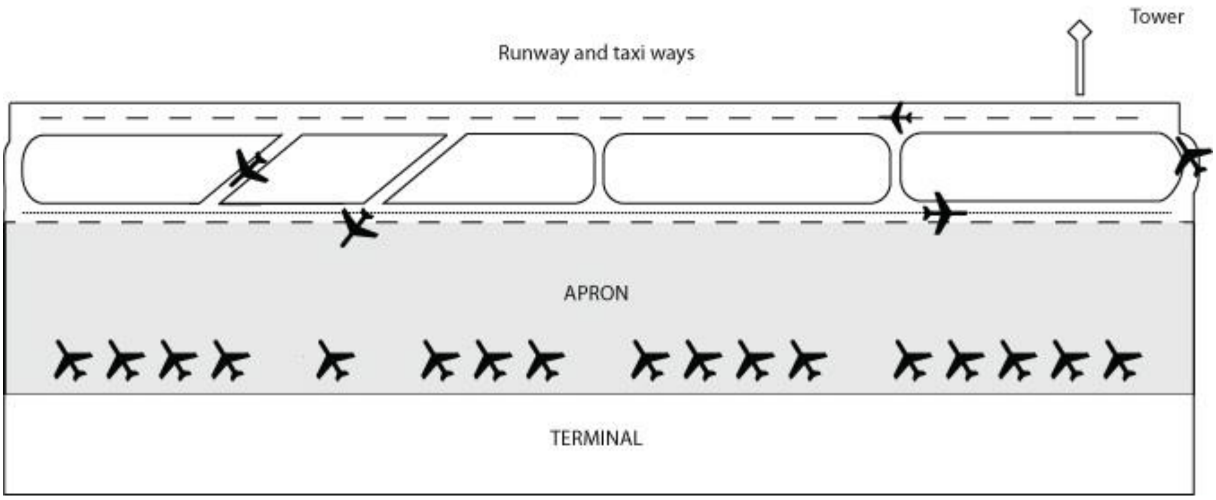



Figure 15: Example Cost-Effective airport layout

#### 5.4.3.1 Tower

In case of areas with multiple airports (London, Frankfurt, Paris, etc.) or small traffic density areas one remote tower will service multiple airfields. This will be supported by enhanced self-separation and navigation capabilities of the aircraft. The emphasis will be on aircraft equipment instead of ground based devices, for example: the taxiing and ground movement of the aircraft will be supported by synthetic vision and GPS based navigation.

#### 5.4.3.2 Runway and taxiways

Taking into consideration that the emphasis will be on aircraft equipment instead of ground based devices, such as synthetic vision, GPS based navigation and self-separation, the currently used runway and taxiway equipment (ILS, MLS, PAPI, lightening, etc.) will partly disappear or be substituted by on-board equipment. Thus maintenance and operating cost will be reduced.

#### 5.4.3.3 Apron

Aircraft can be subdivided in two main categories: short- and long-haul. The apron will be configured in a way that can service both types of aircraft in a flexible manner. Stands will be designated by the smart terminal system according to the incoming traffic mix providing exact coordinates of stands for aircraft. The airplane will find its way to its stand based on this information using its on-board equipment.

#### 5.4.3.4 Stand

The stands will be equipped with several underground networks, such as fuel, energy, potable water or waste water removal. The difference between short- and long-haul flights will be the equipment needed: for long-haul flights a bridge will be provided for boarding/ disembarking and extra network connection points will be available as the size of the long-haul aircraft will be considerably bigger.

### 5.4.4 Terminal layout

In terms of layout/structure it is foreseen that surface transport will be much quicker, more efficient and highly predictable. In addition, security processes will probably take up less time for passengers. As a result the future airport terminal may change a lot from nowadays. The current airside part of the terminal might evolve to a much smaller, minimised terminal. On the other hand the current landside part of the terminal may evolve to become a transport node which is not necessarily located at the airport but can be located within the city. These transport nodes and service centres can be integrated in a railway station, providing fast, direct train service to actual flights for example.

Since terminals are one of the biggest cost centres for airports, the operational costs of the future airport can be reduced by increasing revenues from other services through service centres shared with other transport modes.

In the future a cost efficient airport must be ‘green’ as well. The terminal buildings will be built to using passive technology, leading to an airport with zero net energy consumption and zero carbon emission. It will be lighted by led lamps which will switch on only on demand: when nobody is present it switches off, thus saving energy and money. During the day plastic mirrors will collect and filter (from UV and other light waves that harm plastic materials) sunlight and carry by fibre plastic into the building. Thanks to this technology no artificial light will be needed during the day. Trash will be recycled while the waste water treated and re-used.

The terminal buildings will also employ smart technology, which will distribute and conserve energy through the building where it is needed most. Also, many buildings use solar energy producing more electricity than they consume. They will be connected to a smart grid, selling power back and thus redistributing the energy to where it is needed most.

Assuming that there will be intermodal hubs the following alternatives exists regarding the location of the terminal:

- **Intermodal hub at the airport:** the airport will become an intermodal hub providing different connections such as train, metro or taxi. The terminal building will become large and will include catering and shopping facilities as well.
- **Airport moved to the city centre:** in this case the intermodal hub will be situated in the city centre and will be connected to the airport by dedicated fast train line. The check-in and security check will be done at the hub, so at the airport only a small building will exist providing check-in and security facilities for those who are arriving to the airport individually (taxi or car).

The current floor plan of the terminal buildings is determined by the current functionalities they should accommodate. Amongst those the most important are check-in, passport control, security check and hosting of passengers in case of prolonged waiting time. Because of these the airport terminal is oversized to make room for artificial bottlenecks for check points and considerable areas for comfortable waiting supported by shopping and eating facilities. In

New technologies, in contrast, may allow to process passengers in a bulk, while the waiting time is reduced. Therefore the floor plan of the new terminal can be simplified without built-in bottlenecks and unnecessary waiting areas.

Regarding the layout the following alternatives are possible:

- **Lean terminal:** a long but narrow terminal building along the apron with minimum facilities inside, such as security check, passport control, catering facilities, rest room and medical service.
- **Satellite terminals:** one larger central terminal with public road connectivity where security checks and passport control is provided; this large terminal is connected underground with smaller satellite terminals via internal transport connections.
- **Underground terminal:** a partly or completely underground terminal minimizing the physical area of the airport.

To exemplify, the below figure illustrates a possible new layout of a lean terminal.

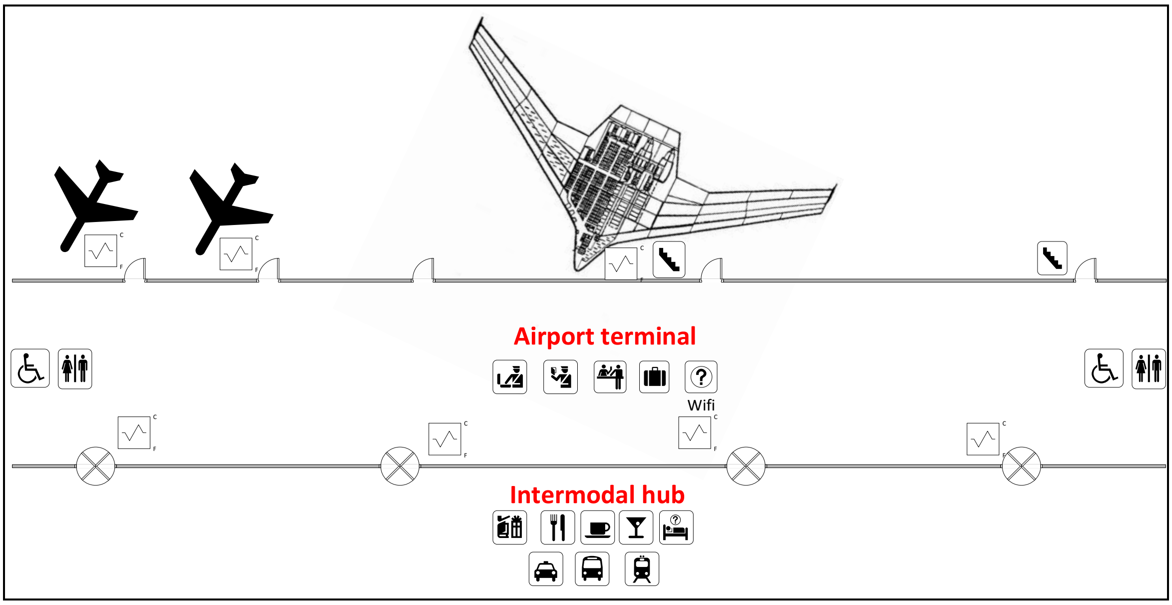



Figure 16: The possible new layout of a lean terminal

**Legend:**

| ITEM | DESCRIPTION | ITEM | DESCRIPTION |
|---|---|---|---|
| | Biometric identification of passengers | | Passenger bridge system as part of the building, or mobile for long-haul flights |
| | Custom Control supported by biometric identification if applicable and THz based scanning technology | | Public transport access points |
| | Immigration Control supported by biometric identification if applicable | | Rest rooms |
| | Electronic identification of passengers | | Rest rooms for disabled passengers |
| Wifi | Wifi connection for personalized information providing for each passenger | | Gift shop |
| | Baggage reconciliation area: optional, passenger may want to receive the baggage at the destination point (hotel, home, meeting room, etc.) | | Restaurant, Coffee bar, Bar |
| | Hotel, Hotel information | | |

The terminal building itself will be very narrow, as the passengers will only need to cross it, and identification of passengers will happen upon entering the terminal, while the boarding check will take place on board the aircraft.

#### 5.4.4.1 Sustainable building

A sustainable or green building implies an environmentally responsible and resource-efficient usage of materials and processes to reduce the overall impact of the built environment on human health and the natural environment.

A green building includes the following aspects:

- Efficient use of energy, water and other resources,
- Reducing waste and pollution,
- Protection of occupant health.

#### 5.4.4.2 Sustainable energy use

Clean energy will be a basic need in 2050. Depending on the location of the airport, the following resources can help renewable energy production:

- Geothermal energy: Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma. Geothermal hot water can be used for many applications that require heat, include heating buildings.
- Biomass: Biomass is biological material from living, or recently living organisms, most often referring to plants or plant-derived materials. It will be primarily used as fuel, although it can be used for electricity production by means of advanced gasification processes.
- Solar energy: Solar power is the conversion of sunlight into electricity, which can provides inclination to different electronic systems.
- Hydropower: hydropower is the way of producing electrical power through the use of the gravitational force of falling or flowing water. It can be used for ensuring electricity for different systems at airport.
- Nuclear energy: Nuclear power is the use of sustained nuclear fission to generate heat and electricity.

#### 5.4.4.3 Waste management

Waste water can be filtered by reverse osmosis. After filtration the water is cleaned by ultraviolet rays. This way the costs can be reduced.

#### 5.4.4.4 Heat insulation

Aerogel or insulation panel technologies will be used for heat insulation of buildings, including walls and windows to reduce the costs of heating/ cooling.

### 5.4.5 Turnaround process

Finally, the CE solutions outlined in section 5.3 also impact the turnaround process at airports. In the CE airport, the servicing of aircraft will require less vehicles then today due to the following improvements:

- The aircraft will be capable of self-taxiing; therefore no pushback will be needed.
- Thanks to synthetic vision in cockpit, there will be no need for marshalling.

- An underground pipe system will provide fuel, electricity and potable water and will help removing of remove waste water, which will substitute mane of the servicing vehicles.
- Short-haul aircraft will be equipped with self-servicing equipment, such as a boarding device; they will also not require catering.

All vehicles enabling the servicing of the aircraft during turnaround will be powered by hydrogen, thus saving money and reducing environmental pollution.

The vehicles will be equipped by a tablet which is connected to the airport's intranet system. This will enable the staff to have online information about the position and status of all the flights. They will be also be equipped by GPS allowing the airport turnaround management system to know their exact location which will help the planning of the turnaround.

# 6 Values assessment of the Cost-Effective airport concept

This chapter discusses the validation of the Cost-Effective (CE) airport concept, which is based on the outcomes of the first validation cycle in WP3. The results are obtained from a workshop which included a brainstorm/gaming session, a strategy game, and expert judgement of the concept ideas. This chapter presents the post-analysis of the workshop results and draws conclusions on the validity and expected benefits of the CE airport concept's ideas. It furthermore addresses which ideas from the Ultra-Green (UG) and Time-Effective (TE) airport concepts are expected to be beneficial for the CE airport concept.

The results are discussed as follows. Section 6.1 summarises the operation impact of the CE airport concept. Section 6.2 presents the final value function that is established by expert judgement and which has been used for the validation study, after which 6.3 discusses the validation results of the experts gaming and judgement sessions respectively. The chapter is concluded in Section 6.4 with the best ideas and perspective of the CE airport concept and presents recommendations for further development.

## 6.1 Identification of operational changes in the Cost-effective concept

The following table shows the affected areas and related process that we will change due to the previously detailed new solutions:

Table 51: The affected areas and related process

| CONCEPT IDEA | AFFECTED OPERATION AREA | ASPECTS/PROCESSES AFFECTED | SECONDARY IMPACT AREA |
|---|---|---|---|
| Biometric identification of passenger | Passenger related procedures | Check-in<br>Boarding<br>Passport check | Check-in time<br>Boarding-time<br>Safety level<br>Energy usage |
| THz based passenger screening | Passenger related procedures | Security check | Security check time<br>Energy usage<br>Security level |
| Check-in using smart devices (tablet, smart phone, etc.) | Passenger related procedures | Check-in<br>Boarding | Check-in time<br>Check-in area (terminal) |
| Self-boarding gate | Passenger related procedures | Boarding | Boarding time<br>Boarding area (terminal) |
| SBAS/ GBAS | ANSP related processes | ATM | Safety<br>Navigation precisely<br>Operation circumstances |

| CONCEPT IDEA | AFFECTED OPERATION AREA | ASPECTS/PROCESSES AFFECTED | SECONDARY IMPACT AREA |
|---|---|---|---|
| Synthetic vision in cockpit | ANSP related processes<br>Airport maintenance related processes | ATM<br>Landing/ Take-off | Energy usage<br>Maintenance costs (runway, taxiway, apron)<br>a/c servicing equipment |
| 4D trajectory | ANSP related processes | ATM | Airspace usage flexibility |
| D-ATIS | ANSP related processes | ATM | Information availability<br>Situational awareness |
| SWIM | ANSP related processes | ATM<br>Turnaround | Information availability<br>Situational awareness |
| Remote tower | ANSP related processes | ATM | Maintenance costs (staff, equipment) |
| door-to-door transportation of the baggage | Baggage related processes | Baggage transfer | Baggage transfer time<br>Baggage drop-off/ pick-up area |
| Self-servicing solutions for aircraft (e.g. boarding) | Aircraft related processes | Turnaround | Turnaround time<br>a/c servicing equipment/ staff<br>Terminal floor plan |
| Taxiing with electric motors | Aircraft related processes | Turnaround | a/c servicing equipment/ staff |
| Fuelling through multiple pipes | Aircraft related processes | Turnaround | Turnaround time<br>a/c servicing equipment/ staff<br>Maintenance costs |
| underground pipe system (potable water, waste water) | Aircraft related processes | Turnaround | Turnaround time<br>a/c servicing equipment/ staff<br>Maintenance costs |
| Usage of state of the art lighting | Building maintenance | Turnaround | Energy usage |
| Active building technology | Building maintenance | Turnaround | Energy usage |
| Self-cleaning materials (terminal, aircraft) | Building maintenance | Turnaround | Cleaning equipment (terminal)<br>Turnaround time<br>a/c servicing equipment/ staff |

## 6.2 Composing a value function to evaluate the concept

### 6.2.1 Determination of the value function

A Cost-Effective value function has been established as part of the Concept Development Methodology (CDM) in D2.1.2 [24]. The low-level objectives per concept where established iteratively throughout the project, and for the further definition of the value function. Recalling the value function from D2.1.2:

$$\Delta V(AP_{2011}^{2050}) = \lambda_E \left( \frac{E_{2050}}{E_{2011}} \right) + \lambda_M \left( \frac{M_{2050}}{M_{2011}} \right) + \lambda_S \left( \frac{S_{2050}}{S_{2011}} \right) \quad (1)$$

Where $\Delta V$ represents the change in value, $\lambda_i$ represents the weight of the different key performance areas, and E, M, and S refer to economics, mobility, and sustainability respectively. Taking $\omega_i$ as the weight of the specific low-level attributes *i*, *tj* as time, and δ as delay level, the time-efficient element *M* in The contribution per area in equation (1) can be described further by its low-level attributes in the form:

$$\left( \frac{Economics_{2050}}{Economics_{2011}} \right) = \omega_1 \left( \frac{Cost_{aeron,2050}}{Cost_{aeron,2011}} \right) + \omega_2 \left( \frac{Cost_{nonaeron,2050}}{Cost_{nonaeron,2011}} \right) + \omega_3 \left( \frac{Income_{aeron,2050}}{Income_{aeron,2011}} \right) + \omega_4 \left( \frac{Income_{nonaeron,2050}}{Income_{nonaeron,2011}} \right) \quad (2)$$

Similarly, the low-level objectives of time-efficiency and sustainability can be included. The (final) value function that has been used during the workshop includes 16 low-level objectives in total. Workshop participants had the opportunity to propose new attributes that could be included, although were not taken into account in the exact analysis during the workshop.

### 6.2.2 Determination of the weight factors

The weight factors have been determined per concept from expert judgement during the WP3 validation workshop. All stakeholders (airport, airline, passenger, Air Navigation Service Provider (ANSP), and industry) were asked to – from a cost-effective point of view – give (1) a division of importance to the weights for the three areas $\lambda_i$, and (2) give a division of importance to the weight factors of the low-level objectives $\omega_i$. The weight factors given by the experts were averaged from the different stakeholder roles during the workshop. The final division for the Key Performance Areas (KPAs) is given in **Error! Reference source not found.**.

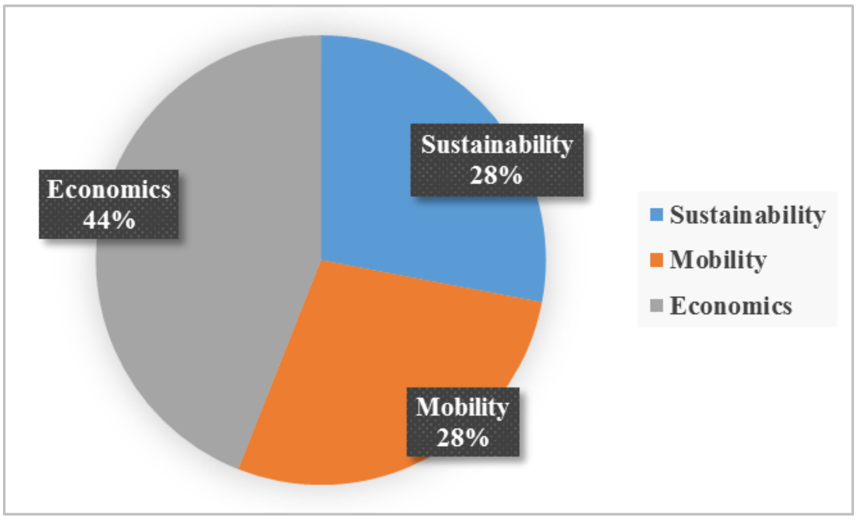



Figure 17: Division of importance of the three KPAs for the CE airport concept.

Table 52: Division of importance of all low-level objectives for the CE airport concept

| LOW-LEVEL OBJECTIVE | IMPORTANCE FOR THE COST-EFFECTIVE CONCEPT (I.E. WEIGHT FACTOR) |
|---|---|
| Reduce Aeronautical Cost | 0,24 |
| Reduce Non-aeronautical cost | 0,28 |
| Increase Aeronautical income | 0,13 |
| Increase Non-aeronautical income | 0,35 |
| Minimise taxi times | 0,11 |
| Minimise turnaround time | 0,14 |
| Minimise delays | 0,18 |
| Minimise travel time through airport | 0,08 |
| Minimise waiting time between processes | 0,09 |
| Minimise processing time | 0,10 |
| Minimise connecting times between modes | 0,30 |
| Keep noise within or below legal limit | 0,24 |
| Reduce energy use | 0,18 |
| Reduce emissions | 0,18 |
| Optimal use of resources (recycling) | 0,22 |
| Optimal use of water | 0,18 |

The following can be observed from the table: time-efficiency and sustainability still play an important role when determining the added value with 28-28%, while the most important is Economics with 44% of weight. Going into details and considering the low-level objectives, the increasing of non-aeronautical revenues is the main driver. The increase of aeronautical revenues received low weights, while the minimization of connecting times received high values.

### 6.2.3 Set-up of the validation workshop

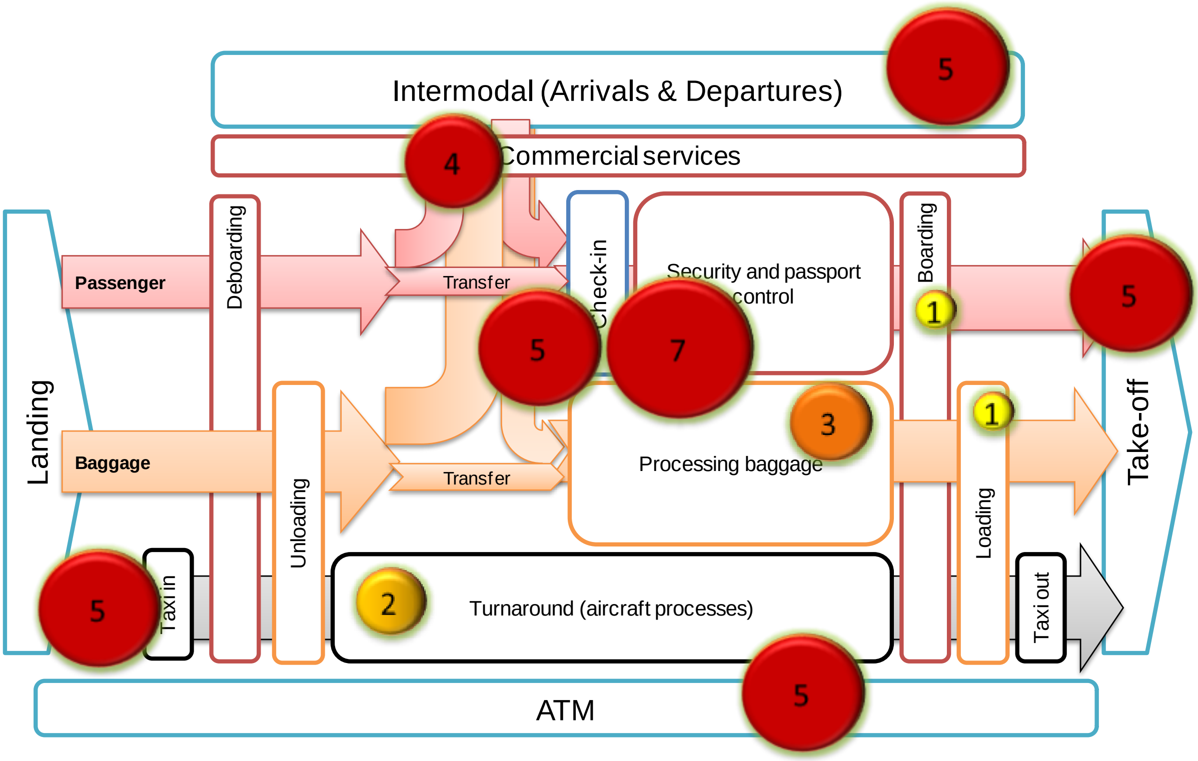
The validation of concept ideas has been performed in two ways: (1) an expert judgment gaming session and (2) a value assessment of the chosen ideas. The gaming session included all ideas developed in WP4, including the UG and TE concept ideas. Experts were asked to choose the best ideas from their roles and from a cost-effective point of view. The 25 ideas that came out of the gaming session were evaluated by the experts using the value structure. This section discusses these results.

### 6.2.4 Results of expert gaming session

**Error! Reference source not found.** shows the invariant processes chart with the amount of chosen deas per process in the expert's gaming session.

The chosen ideas show a quiet balanced picture: most of the ideas are related to the passenger processes, such as security and passport control (7 ideas), check-in (5 ideas), intermodal activities (5 ideas) and commercial services (4 ideas). The rest of the ideas are connected to aircraft related processes, such as Taxi in (5 ideas), ATM (5 ideas) and take-off (5 ideas). Only few ideas are connected to the processing of the baggage (3 ideas), turnaround (2 ideas), boarding and loading (1-1 idea).

Figure 18: Ideas chosen by experts per process.




The following table shows the ranking of the ideas discussed at the workshop as it was rated by the experts.

Table 53: Ranking of ideas from expert's gaming session.

| IDEA | CONCEPT | POINTS |
|---|---|---|

| IDEA | CONCEPT | POINTS |
|---|---|---|
| Idea 7: Electric Ground Movement | UG | 25 |
| Idea 37: Intelligent ICT Supported Airport | UG | 21 |
| Idea 29: Walk Through Security Check Corridor | TE | 18 |
| Idea 2: Magnetic Levitation For Take-off & Landing | UG | 18 |
| Idea 12: Electric Guided Taxi System | TE | 14 |
| Idea 26: Door-to- Door Transportation Of Baggage | CE | 13 |
| Idea 32: City And Single Central Terminal | UG | 13 |
| New 3: Process integrator for all users optimizer for all processes and services | New | 13 |
| Idea 6: Remote Tower | CE | 13 |
| New 2: Airport as entertainment area (Golf, Shopping...) | new | 11 |
| Idea 10: Electric Taxi For Door-to-door Airport Transport | TE | 11 |
| Idea 27: Microwave And Terahertz Metrology For Homeland Security | CE | 10 |
| Idea 38: Intermodal SWIM | CE | 10 |
| Idea 1: Dual/Split Threshold Runway | UG | 9 |
| Idea 3: Electric Engine Accelerators For Take-off | UG | 9 |
| Idea 39: Integration Of Renewable Energy Infrastructure In The Platform | UG-CE | 8 |
| Idea 11: High Speed Aircraft Taxi System | TE | 7 |
| Idea 8: Synthetic Vision In Cockpit | CE | 6 |
| Idea 5: 3D Holographic HMI Tower/Apron Controller Position | CE-TE-UG | 5 |
| New 5: Public polls to optimize the load factor of A/C to destination | New | 5 |
| New 4: Smart aircraft deciding roads and airport operations themselves | New | 4 |
| Idea 16: On-board Self-boarding Gate | CE | 4 |
| Idea 28: Biometric Identification Of Passenger | CE | 4 |
| Idea 36: Door-to-door Integrated Transportation Chain | CE | 4 |
| New 1: Cloud System For Tower (Automatic ATM) | new | 1 |

The first 5 ideas originate from a different concept than CE, although some of them are also covered by the cost-effective solutions detailed in section 5.3:

- Electric Ground Movement, Electric Guided Taxi System: the CE proposal also is to use electric solutions for taxiing and push-back.
- Intelligent ICT Supported Airport: in the CE concept the whole terminal is covered by an intelligent ICT system which connects automatically to the passenger smart device and gives information about boarding time, boarding gate, path finding, etc.
- Walk-Through Security Check Corridor: In the CE concept, the whole terminal is covered by a THz based system which detects any dangerous materials, potential weapons.

During the workshop the following new CE ideas were proposed by the experts involved:

- Process integrator for all users, optimizer for all processes and services
- Airport as an entertainment area (Golf, Shopping...): this solution makes the airport terminal interesting also for ‘non-flying’ public and generates additional revenue for airports.
- Public polls to optimize the load factor of aircraft towards their destination

- Smart aircraft deciding roads and airport operations themselves: in small density areas the available road network (motorways) can be used for landing and take-off.
- Cloud System For Tower (Automatic ATM): in this case the aircraft themselves could substitute the air traffic controllers, as all the information would be available for everyone because it would be uploaded into the cloud.

In addition, there are also some ideas in the CE concept that were not chosen by the experts at the workshop, although they are still part of the concept:

- 4D- trajectory
- Active building technology
- Check-in using smart devices: partly covered by 'Intelligent ICT supported airport'
- D-ATIS
- Self-cleaning materials (terminal, aircraft)
- Taxiing and push-back with electronic motor: partly covered by ' Electric Ground Movement'
- THz based passenger screening
- Usage of state of the art lighting

The reason for this can be a lack of time: the participants had limited time to review and to understand each concept idea and some of the ideas are similar/ overlapping with other concept ideas. Another reason can be that some ideas don't give additional benefits in itself, only when combined with other proposed solutions.

### 6.2.5 Improvements to the Cost-Effective concept solutions

For some ideas improvements were suggested during the gaming session, which are summarised below and which could improve the cost-effectiveness of the ideas considered.

Table 54: Suggested improvements to some of the ideas

| IDEAS | PROPOSED IMPROVEMENT |
|---|---|
| Idea 1: Dual/split threshold runway | Runway + highway integration for low density populated areas |
| Idea 11: High speed aircraft taxi system | Electronic speed control done by Total Airport Management |
| Idea 3: Electric engine accelerators for take-off | Mixed with electric taxi solution, a/c engines just for en-route |

## 6.3 Value analysis of the Cost-Effective concept solutions

The experts were also asked to determine the impact of their chosen solutions on all the value attributes. Using this data and the value function established in Section 6.2 the value added per idea can be calculated.

### 6.3.1 Most value-adding ideas

Using the calculated added value, a ranking of ideas has been made. For the CE airport concept, two new ideas, the ‘Process Integrator For All Users, Optimizer For All Processes And Services’ and the ‘Cloud System For Tower’ received the highest scores, while the ‘High-speed Aircraft Taxi System’ finished on the 3rd place.

Table 55: Expert's value assessment of ideas for the CE airport concept

| IDEAS | CONCEPT | ΔV |
|---|---|---|
| New 3: Process Integrator For All Users, Optimizer For All Processes And Services | new | 41,9 |
| New 1: Cloud System For Tower (Automatic ATM) | new | 36,0 |
| Idea 11: High Speed Aircraft Taxi System | TE | 32, 2 |
| Idea 27: Microwave And Terahertz Metrology For Homeland Security | CE | 31,9 |
| Idea 7: Electric Ground Movement | UG | 30,6 |
| Idea 32: City And Single Central Terminal | UG | 30,4 |
| Idea 12: Electric Guided Taxi System | TE | 29,7 |
| Idea 29: Walk Through Security Check Corridor | TE | 28,7 |
| Idea 16: On-board Self-boarding Gate | CE | 26,2 |
| Idea 2: Magnetic Levitation For Take-off & Landing | UG | 25,1 |
| New 5: Public polls to optimize the load factor of a/c to destination | new | 22,0 |
| Idea 7: Electric Ground Movement | UG | 19,6 |
| Idea 5: 3D Holographic HMI Tower/Apron Controller Position | all | 19,1 |
| Idea 6: Remote Tower | CE | 16,2 |
| Idea 39: Integration of renewable energy infrastructure in the platform | CE-UG | 15,5 |
| Idea 28: Biometric Identification Of Passenger | CE | 15,3 |
| Idea 37: Intelligent ICT Supported Airport | UG | 14,3 |
| Idea 8: Synthetic Vision In Cockpit | CE | 13,4 |
| Idea 36: Door-to-door Integrated Transportation Chain | TE | 12,7 |
| Idea 38: Intermodal SWIM | CE | 12,2 |
| Idea 1: Dual/Split Threshold Runway | UG | 11,3 |
| New 2: Airport as entertainment area (Golf, Shopping...) | new | 7,3 |
| Idea 3: Electric Engine Accelerators For Take-off | UG | 5,9 |
| Idea 26: Door-to- Door Transportation Of Baggage | CE | -1,5 |
| Idea 10: Electric Taxi For Door-to-door Airport Transport | TE | -5,9 |

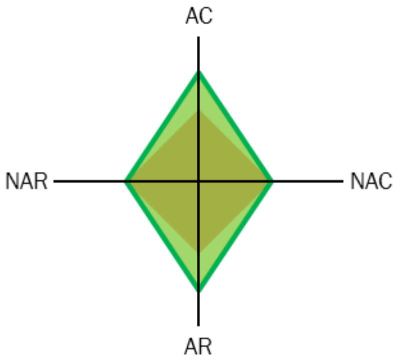
### 6.3.2 Validation of the cost-effective specific ideas

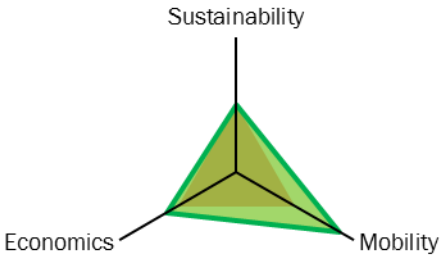
In order to analyse the impact of CE concept solutions in more detail, the following sections show two radar plots. The left plot is indicating the impact of the idea on the four value attributes (KPIs) related to cost-effectiveness: NAR – Non-Aeronautical Revenue, NAC – Non-Aeronautical Cost, AC – Aeronautical Cost, AR – Aeronautical Revenue. The right plot is showing the value contribution to the three airport focusses (Key Performance Areas (KPAs)), which is calculated using the composed value function. The latter plot is thereby also indicating from a higher level how the CE ideas are affecting sustainability and time-efficiency.

#### 6.3.2.1 Intermodal SWIM

The Intermodal SWIM has no effect on non-aeronautical activities, whilst it has a beneficial effect on aeronautical revenue and also on costs. The introduction of Intermodal SWIM enables access to more information than today, thus enabling better planning of the aircraft's turnaround and connection. Better predictability indicated by Intermodal SWIM will lead to lower delay costs, better utilization of equipment and stands. In an indirect way, this will contribute to shorter turnaround windows, therefore higher income.

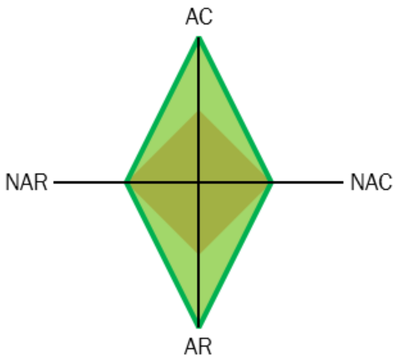
The Intermodal SWIM has the most positive effects on Mobility, as the interconnection of the different transportation vehicles will be better resulting more precise departure and arrival times.

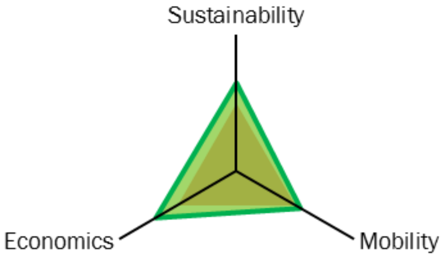



#### 6.3.2.2 SBAS/GBAS

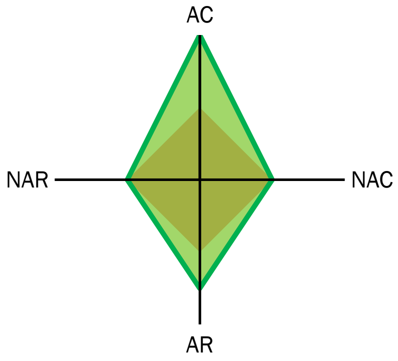
The implementation of SBAS/ GBAS is expected to lead to a more precise navigation of aircraft thanks to the more precise positioning systems. This allows more aircraft to be handled safely in the same airspace which has a positive effect both on aeronautical revenues and costs. This solution doesn't affect sustainability and Mobility as it is related to the ANSP's activities.

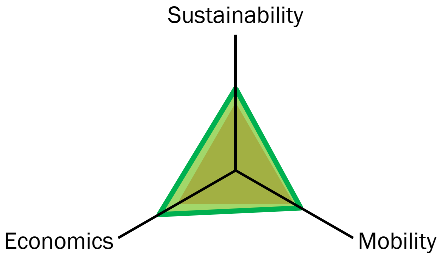


#### 6.3.2.3 Synthetic vision in cockpit

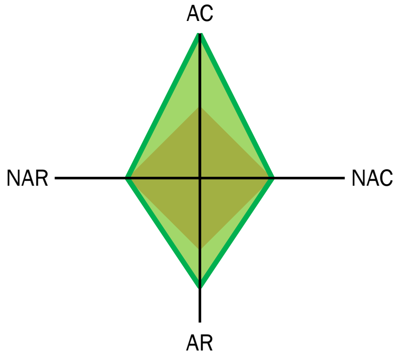
Synthetic vision helps the staff of the cockpit by enabling a better situational awareness related to the outside world regardless of the weather. It decreases cost, because less aerodrome installed equipment is needed (Traffic lights can be eliminated, runway lights can be reduced, taxiway signs can be substituted with augmented reality, etc.) It increases aeronautical revenue, because more aircraft can be handled in the same airspace under all-weather operations. This solution doesn't affect Sustainability and Mobility as it is related to the ANSP's activities.

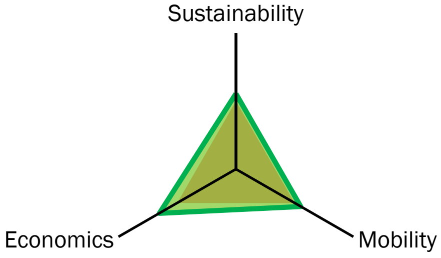



#### 6.3.2.4 D-ATIS

D-ATIS replaces the current voice based communication with automatic, digitally transferred information. This way it reduces costs, as less staff and equipment is needed; in addition, it increases revenues due to more, digitally available, up-to-date information. This solution doesn't affect Sustainability and Mobility as it is related to the ANSP's activities.

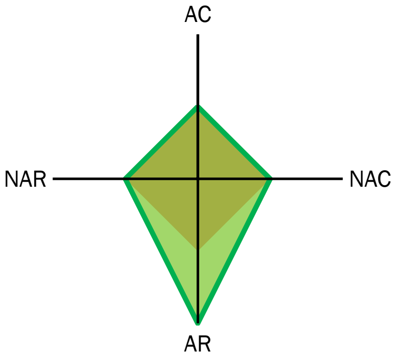


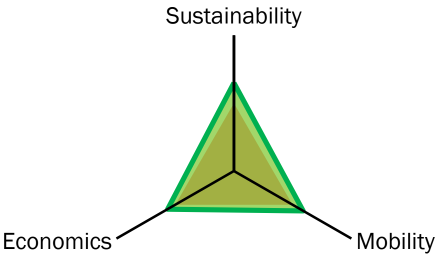




#### 6.3.2.5 4D trajectory

Today's schedule of flights at a particular airport is negotiated and finalized about half a year before the actual flights take place. During the creation of the schedule stakeholders have to foresee the fact that actual arrival and departure times are highly affected by the actual ANSP capacity for that particular day. Therefore, stakeholders include appropriate gaps into the schedule to accommodate last minute changes imposed by ANSP. This affects negatively the airport capacity.

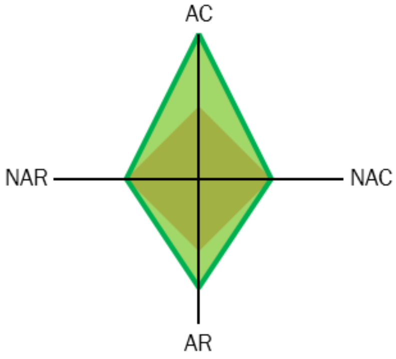
By generating and accommodating 4D trajectories such gaps in the schedule will be eliminated or considerably shortened. Therefore the airport capacity will be better utilized resulting in a better use of available resources increasing income. Besides that, the 4D trajectory eliminates en-route slots thus reducing waiting time and increasing mobility. Point to point routing results in shorter flight distances thus reduces fuel consumption and emissions.

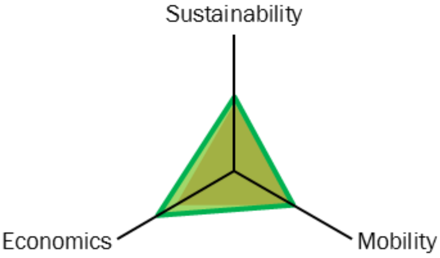



#### 6.3.2.6 Remote tower

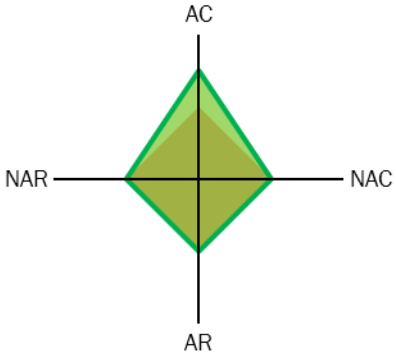
In remote areas with small airports air navigation services can be provided by an ANSP crews operating from a remote tower to cover several airfields and airspaces. In this case obviously the related costs would decrease drastically. This solution doesn’t affect Sustainability and Mobility as it is related to the ANSP’s activities.

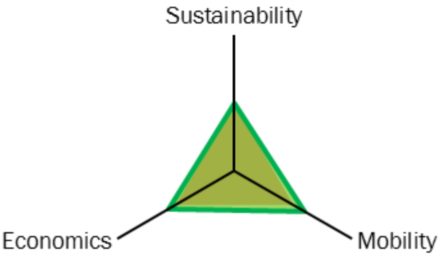



#### 6.3.2.7 On-board self-boarding gate

The on-board self-boarding solution eliminates airport based boarding gates and related staff, thus way reducing aeronautical costs. The other attributes/KPIs are not affected by this solution. This solution – beside Economics- has a positive effect also on mobility, because it contributes to fast boarding.

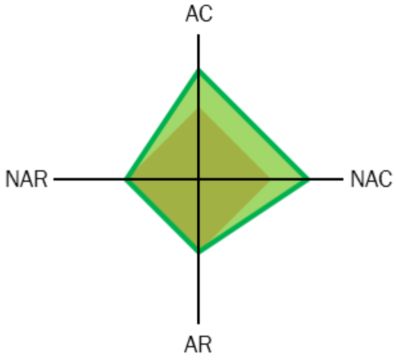


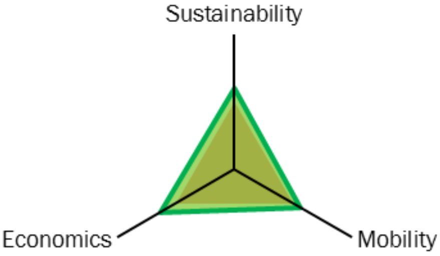




#### 6.3.2.8 Self-cleaning materials

Self-cleaning materials requires less staff for cleaning of aircraft and terminals, having a positive effect on aviation and non-aviation related costs.

As the self-cleaning materials require less chemicals to be applied for cleaning, these materials will lead to less waste water and thus improved sustainability. Mobility is positively affected by the shorter cleaning time.

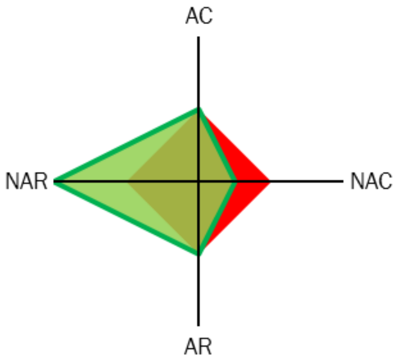


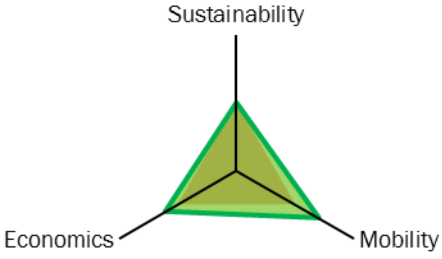




#### 6.3.2.9 Door-to-door transportation of baggage

The door-to-door transportation of baggage can result in additional costs for the airport, because it requires additional staff and vehicles for the collection and distribution of the luggage. On the other hand, it opens a new service and provides additional revenues. Furthermore, by collecting the luggage days(s) before departure it is possible to better plan the loading of luggage.

Beside Economics this solution has positive effect also on mobility since it reduces the loading time of the aircraft (no need to wait for passenger baggage) and substitutes baggage drop off for passengers.

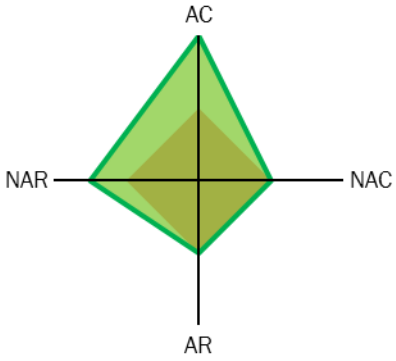


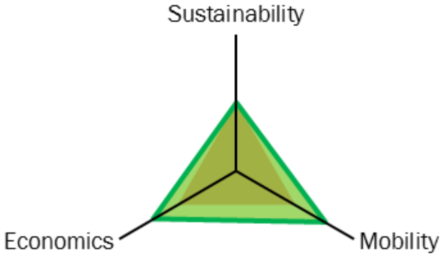




#### 6.3.2.10 Travel organizer

The airport terminal has an ICT system that allows immediate connection to the passengers' smart devices. This solution enables automated message exchange between the airport terminal's system and the passenger's smart device. This way the passenger automatically can be informed about the boarding time, boarding gate, way to the boarding gate or other services. Additional information can be provided to the passenger by the airport upon request for extra fee thus increasing the Non-aeronautical revenue. In addition this solution substitutes the current electronic tables and displays thus reducing Aeronautical costs.

Beside Economics this solution supports also mobility because it aids passengers by providing accurate data on aircraft departure and also helps way finding, thus reducing the possibility of delays.

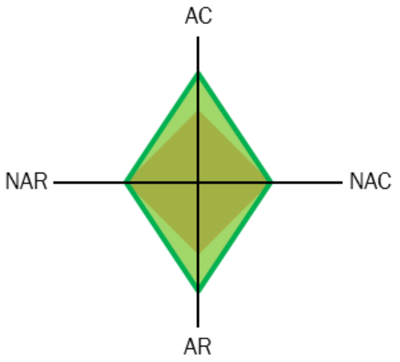


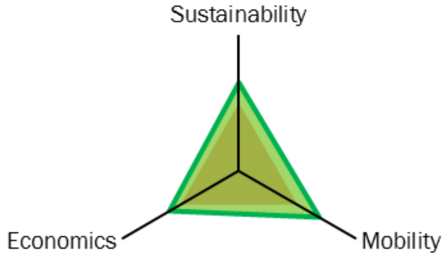




#### 6.3.2.11 Fuelling through multiple pipes

By using an underground pipe system, there is no need for a fuelling truck, because the fuelling connection will be available at each stand. By using more pipes the process can be speed up so the turnaround time can be shortened. This solution reduces the Aeronautical costs because fewer vehicles are needed and the speeding up of the turnaround enables better usage of the stands.

This solution provides benefits also for sustainability, because the substitution of vehicles results in less emissions. From the perspective of mobility it also has a positive effect, because the usage of multiple pipes reduces the turnaround time.

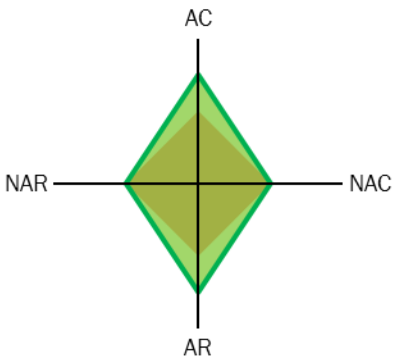


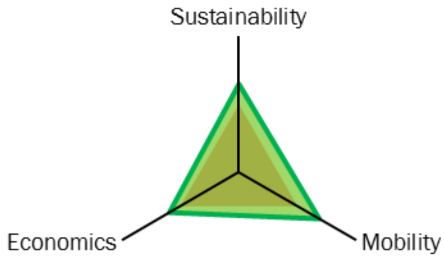




#### 6.3.2.12 Underground pipe system

An underground pipe system can be used not only for fuelling, but also for the provision of drinking water and removal of waste water. Using pipe systems, which are available at each stands, there is no need to wait for servicing vehicles, so the turnaround time can be shortened. The shorten turnaround results in a better utilization of airport stands.

This solution provides benefit also for sustainability, because the substitution of vehicles results in less emission. From the perspective of mobility it also has a positive effect, because the usage of underground pipes reduces the turnaround time.

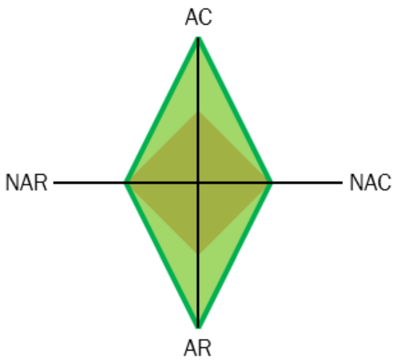


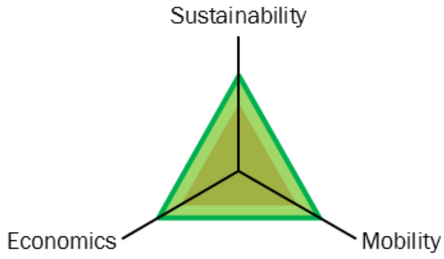




#### 6.3.2.13 Self-servicing solutions for aircraft

Reducing the number of vehicles needed for servicing aircraft the turnaround time can be reduced, because there is no need to share the vehicle with other aircraft in the same time and there is no need to wait for services. For this purpose the aircraft can be equipped with self-servicing facilities. As these activities are provided by the aircraft itself, the airport will not need to handle a vehicle park for the same reason, reducing aeronautical costs. At the same time the turnaround time can be shortened, since more aircraft can be served in the same time period, increasing throughput.

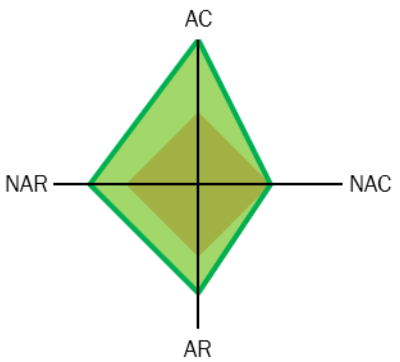
This solution provides benefit also for sustainability, because the substitution of vehicles results in less emission. From the perspective of mobility it also has a positive effect, because the usage of underground pipes reduces the turnaround time.

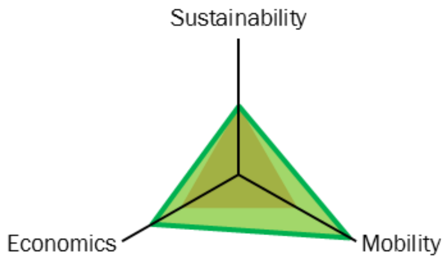



#### 6.3.2.14 THz based passenger screening

In the case of THz based passenger screening the whole territory of the terminal is covered by devices which are able to detect any dangerous materials or potential weapons. The aeronautical costs will decrease, because there will be no need to use security gates. The aeronautical revenues will increase, because the throughput will be much higher. The non-aeronautical revenues will also increase, because the passengers will spend more time in the commercial area knowing that a security check doesn't require any extra time.

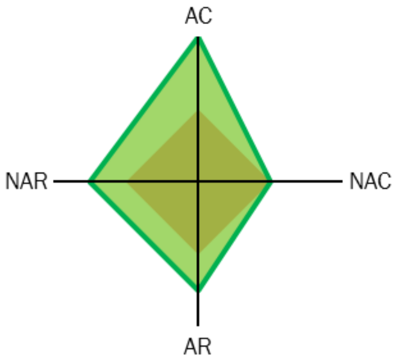


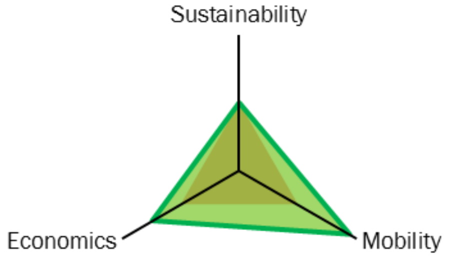




This solution provides benefits also for mobility by reducing the time required for passengers to be security checked.

#### 6.3.2.15 Biometric identification of passengers

Biometric identification of passengers can happen at several points of the journey: upon take off the bus, upon arrival to the airport terminal and so on. It can substitute for example check-in, if upon entering the airport terminal the automatic passenger identification recognises the passenger and performs check-in.



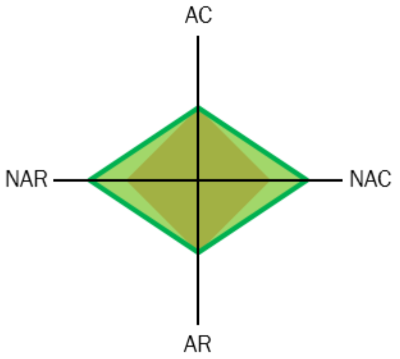



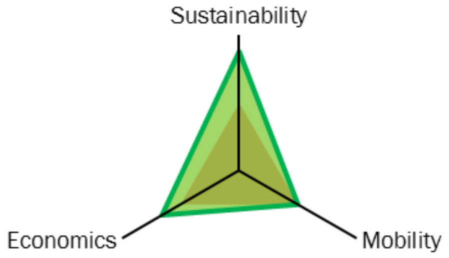

This solution provides benefits also for mobility by reducing the time required for passengers to be identified at check-in.

#### 6.3.2.16 Active building technology

Active building technology, which takes into account also the environmental facilities of the spot, can help the reduction of the Non-aeronautical costs, such as heating, lighting and energy.

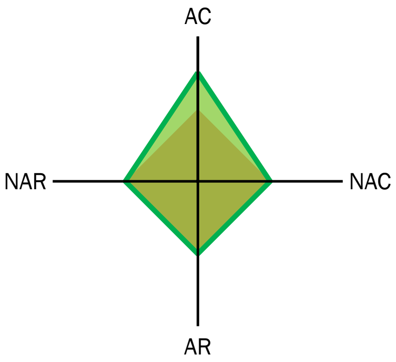
In regards to sustainability its positive effect is obvious: temperature control (both heating and cooling) needs less energy, artificial lighting is only required in few hours a day.

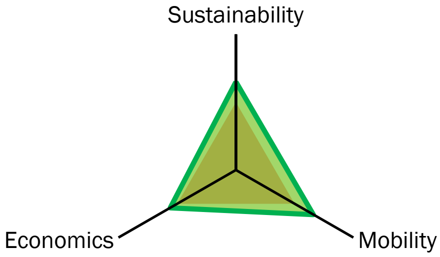



#### 6.3.2.17 Usage of state of the art lighting

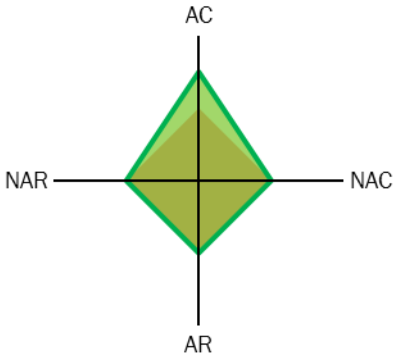
Non-aeronautical costs can be reduced by using LED or FIPEL lighting in public areas, whereas using high-power LEDs for runway/taxiway/apron lighting reduces the aeronautical part of the cost pie.

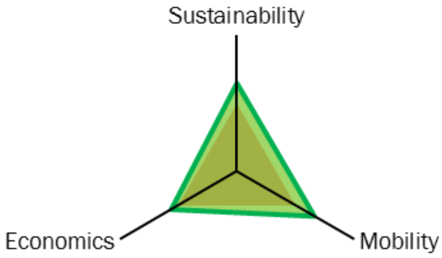



#### 6.3.2.18 Taxiing and push-back with electric motor

Noise/emission fees and fuel costs will be reduced by this zero-emission mode of ground taxi.




### 6.3.3 Limitations to the analysis

The preceding sections showed the valuation of the impact of solution on the KPIs, as expected by aviation experts. It should be noted that this analysis is based on the opinion of one or more experts. As such, the results are just a first estimation of external experts (not involved in the project) of the impact that the CE solutions may have on the four attributes/KPIs defined.

## 6.4 Summary, perspective, and potential of the Cost-efficient concept

The previous sections detailed the results of the UG concept idea validation as part of the AP2050+'s second validation workshop. Results were based on the outcomes of the AP2050+ brainstorm exercise held on June 19 in Madrid. Goal of this exercise was to select concept ideas, rank them, and perform a change-impact analysis to assess the impact of each concept idea on relevant KPIs/attributes. From these exercises and analyses, a list of 'best' ideas has been deduced in two ways.

First, ideas can be ranked based on expert judgement. This relates to the 1st and 3rd part of the validation workshop: the brainstorm exercise to select existing or identify new concept ideas, and the strategy game to rank the selected concept ideas for each role. This resulted in a ranking of concept ideas based on expert judgement.

Second, ideas can be ranked based on the value function. This relates to the 4th part of the validation workshop: the change-impact analysis (ΔV assessment) conducted by the experts. During the analysis, experts assessed the impact (from ++ to --) of each concept idea on each concept attribute/KPI. This resulted in another ranking of concept ideas based on their assessed value.

Below, the best CE ideas are given both ranked on expert judgement and on value analysis assessment.

### 6.4.1 Best ideas for the Cost-effective concept

**Error! Reference source not found.** lists the best ideas coming out of the value analysis (left side) nd expert judgement (right side), visualizing as well the ideas both methods have in common (centre). Several ideas can be considered to be most promising from both analyses, which are displayed in the centre of the figure. It should be noted that these ideas originate from the TE and UG concepts, however they are partially covered by CE concept also, as it was discussed above.

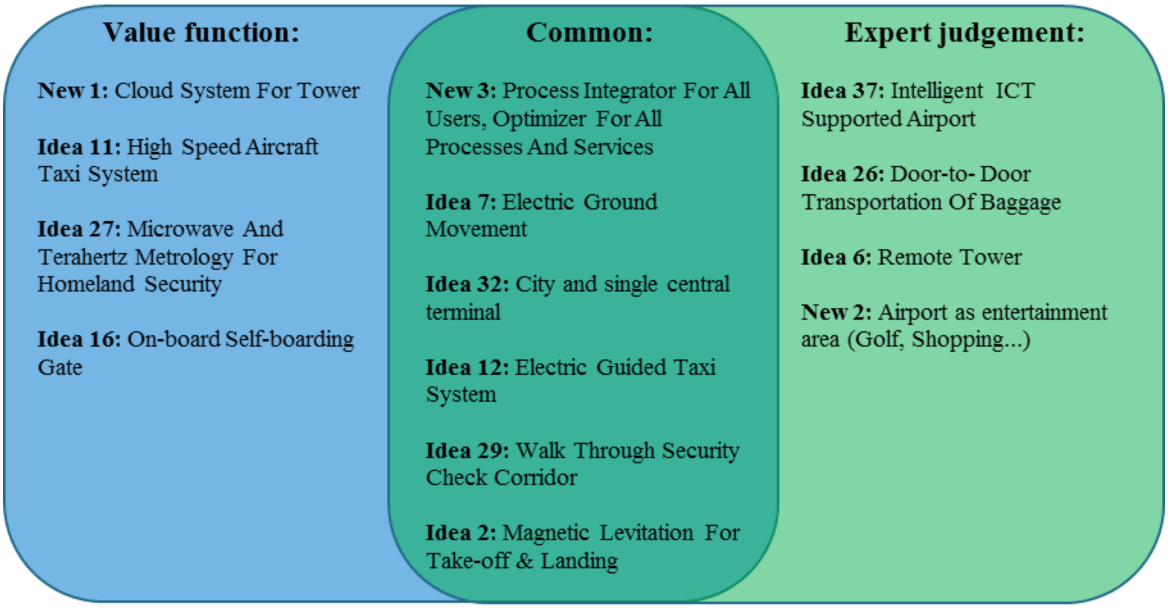



Figure 19: Best ideas from expert judgment, value assessment, and combined.

### 6.4.2 Expert's most promising combinations of ideas

As last part of the validation workshop, after the experts had become familiar with the ideas of Airport 2050+, they were also asked to write down a combination of three ideas that could work together to improve the overall efficiency of the CE airport concept. This lead to the following results, with three idea-combinations for each of the five experts involved the CE session:

Table 56: Expert's judgment on the best ideas for the CE airport concept

| | EXPERT 1 | EXPERT 2 | EXPERT 3 | EXPERT 4 | EXPERT 5 |
|---|---|---|---|---|---|
| Idea I | Idea 27: Microwave and THz metrology for homeland security | Idea 7: Electric ground movement | Idea 7: Electric ground movement | Idea 27: Microwave and THz metrology for homeland security | Idea 36: Door-to-door integrated transportation chain |
| Idea II | Idea 29: Walk through security corridor | Idea 6: Remote tower | Idea 6: Remote tower | Idea 32: City and single central terminal | Idea 2: Magnetic levitation for take-off and landing |
| Idea III | Idea 36: Door-to-door integrated transportation chain | Idea 1: Dual threshold runway | Idea 23: Automation of the turnaround processes | Idea 8: Synthetic vision in cockpit | Idea 27: Microwave and THz metrology for homeland security |

From this list it can be concluded that according to expert judgment the Microwave and THz metrology for security has a big potential for CE, together with electric ground movement and remote tower. Expert's most promising combinations of ideas

### 6.4.3 Additional assessment of idea impact on investment, maintenance and staff costs

Finally, a short additional assessment has been conducted specific for the CE concept. Reason for this is the fact that the CE concept ideas do not only have an impact on the four KPIs of aeronautical costs, and non-aeronautical costs, aeronautical revenues, and non- aeronautical revenues – as assessed during the validation workshop and reported on in this Chapter. Implementing the proposed concept ideas also brings about and has an impact on other, more specific costs: investment costs, maintenance costs, and staff costs. This impact has been assessed and will be discussed shortly below.

#### 6.4.3.1 Investment and maintenance costs

The introduction of new technology that accompanies implementation of the CE concept ideas yields both investment and maintenance costs for this technology. In below table an overview is given of relevant CE concept ideas and their assessed effect on investment and maintenance costs, including a short rationale.

Table 57: The investment and maintenance costs of the technology behind the listed concept ideas

| Concept idea | | Effect on costs[11] | | Reasoning |
|---|---|---|---|---|
| | | Investment | Maintenance | |
| **Passenger related facilities** | Biometric identification of passenger | medium | low | Biometric identification will become common in the future. Although its investment cost can be medium-high, the identification of passengers will be more precise and faster and will require less equipment and staff. |
| | THz based passenger screening | high | low | The coverage of the terminal area with THz based screening devices makes the usage of security lanes and related equipment unnecessary and the related operational staff number can be reduced<br>The development of technology will lower the price of the THz equipment |
| | Check-in using smart devices (tablet, smart phone, etc.) | low | low | In the future the ‘smart/ interactive’ devices will be commonly used in the everyday life. Using these devices for check-in makes unnecessary the current equipment used for check-in. The airport only needs to provide a network which enables check-in related services. |
| | Self-boarding gate on board | - | - | On board boarding facilities substitutes the boarding gate at the airport thus reducing costs. |
| **ANSP services** | SBAS/ GBAS | high | medium | High precision navigation in close vicinity of an airport enables all-weather operations |
| | Synthetic vision in cockpit | - | - | As synthetic vision enables good visibility from the cockpit regardless the weather situation it makes unnecessary the usage of runway and taxi-lights those reducing the navigation and maintenance costs |
| | 4D trajectory | - | - | These services enables more precise navigation by the aircraft and increased situational awareness which results better throughput of the runways even in worse weather situation |
| | D-ATIS | - | - | |
| | SWIM | - | - | Increased situational awareness results more efficient airport services. |
| | Remote tower | low | low | In smaller density areas the ANSPs services of the airports can be assured from one tower instead of establishing independent towers at each airport. |

| CONCEPT IDEA | | EFFECT ON COSTS[11] | | REASONING |
|---|---|---|---|---|
| | | INVESTMENT | MAINTENANCE | |
| **Aircraft related facilities** | Door-to-door transportation of the baggage | - | - | Door-to-door transportation of baggage independently from the passenger enables the better utilization of aircraft hold and increases the level of service<br>On the other hand the baggage flow at the airport will be more predictable and smooth. |
| | Self-servicing solutions for aircraft (e.g. boarding) | - | - | Using self-servicing solutions on aircraft there will be no need for purchase and maintenance of equipment by the airport |
| | Taxiing with electric motors | - | - | Self-servicing aircraft facilities reduces the need for equipment provided by the airport |
| | Fuelling through multiple pipes | medium | low | Fuelling through multiple pipes shortens turnaround time which enables servicing of more aircraft in a time period. It requires less maintenance and operating efforts then the current solutions. |
| | Underground pipe system (potable water, waste water) | medium | low | It requires less maintenance and operating efforts then the current solutions. |
| **Terminal building** | Usage of led lights | low | low | Energy consumption of led light is minimal |
| | Active building technology | medium | low | The overhead expanses of active building is minimal<br>In the future it is expected the sustainable energy sources will be supported by the authorities. |
| | Self-cleaning materials (terminal, aircraft) | low | low | Less effort for maintenance is expected. |

#### 6.4.3.2 Staff related costs

In addition to investment and maintenance costs, the CE concept ideas will also impact staff related costs. In the future, due to the automation of various airport processes an overall reduction of staff numbers can be expected. An airport assistance service may be established to provide all necessary support in case of a problem with automated airport systems or procedures, such as self-check-in or biometric identification. In below table an overview is given of relevant CE concept ideas and their assessed effect on staff related costs, including a short rationale.

Table 58: The changes in numbers of staff

| **CONCEPT IDEA** | | **EFFECT ON STAFF NUMBER** | | **REASONING** |
|---|---|---|---|---|
| | | **EFFECT** | **PERCENTAGE** | |
| **Passenger related facilities** | Biometric identification of passenger | decrease | 100* | In the future the biometric identification will substitute the current processes, although a small number of staff will be provided to handle passengers from countries not equipped biometric identification solutions* |
| | THz based passenger screening | decrease | 90 | the THz based screening technology will need less security personnel to sustain the required level of security due to the novel configuration of the equipment (find more information below the table) |
| | Check-in using smart devices (tablet, smart phone, etc.) | decrease | 100* | the use of smart devices for check-in will completely substitute the current |
| | Self-boarding gate on board | decrease | 100* | the use of self-boarding solutions will completely substitute the current mechanism |
| **ANSP services** | SBAS/ GBAS | - | - | n/a |
| | Synthetic vision in cockpit | decrease | 100 and 80 | this solution will substitute the marshaller service and will decrease the number of staff required for the maintenance of the lighting and navigation system |
| | 4D trajectory | - | - | n/a |
| | D-ATIS | decrease | 15 | the elaboration of the ATIS messages will require less effort |
| | SWIM | decrease | 15.okt | there will be no need for intensive communication and data handling as the it will available straight from the source |
| | Remote tower | decrease | 10 or 100 | Depends on the area served by the new remote tower. The small airports could be substituted by 100%, while the medium or big airports would require almost the same staff number. |
| **Aircraft related facilities** | door-to-door transportation of the baggage | decrease | 70 | Beside door-to-door transportation of the bagged local self-drop-off points will be provided at the airports. The required staff number will decrease as the number of baggage carried by passenger and appearing at the airport will reduce. |

| CONCEPT IDEA | | EFFECT ON STAFF NUMBER | | REASONING |
|---|---|---|---|---|
| | | EFFECT | PERCENTAGE | |
| | Self-servicing solutions for aircraft (e.g. boarding) | decrease | 80 | The airport assistance service will provide necessary help and information for passengers. Mainly the long-haul flights will require catering and stairs/ bridge service. |
| | Taxiing with electric motors | decrease | 100 | this solution will completely substitute the current mechanism (pushback trucks/ tugs) |
| | Fuelling through multiple pipes | decrease | 90 | the self-servicing solutions will also require human interaction, but a smaller number of staff can satisfy this need |
| | underground pipe system (potable water, waste water) | decrease | 90 | the self-servicing solutions will also require human interaction (e.g. a mechanic should connect the water pump to the aircraft), but a smaller number of staff can satisfy this need |
| **Terminal building** | Usage of led lights | - | - | n/a |
| | Active building technology | - | - | n/a |
| | Self-cleaning materials (terminal, aircraft) | decrease | 70 | Due the novel solutions less staff will be required to provide the same level of service both at airport and at the aircraft. |

*staff will be partly allocated to Airport Assistance Service

# 7 Conclusions and recommendations

Within the 2050+ Airport project three airport concepts have been developed for the year 2050 and beyond: the Ultra-Green (UG), Time-Efficient (TE) and Cost-Effective (CE) airport concept. This document reported on the Cost-Effective airport, the airport designed, operated and managed such that the direct and indirect operating costs are minimized whilst keeping revenues as high as possible. Starting point has been the WP2 “2050 Vision” document [4], providing an overall vision on 2050+ and supporting the formulation of bottlenecks to the accomplishment of the Cost-Effective airport. This report outlined the reasons for developing the CE concept, the requirements and goals to be achieved, the reference current-day airport including its cost and revenue structure and a description of the Cost-Effective airport of 2050+ addressing the bottlenecks discerned in current airport operations, infrastructure and cost/revenue structures. In addition, individual CE concept solutions have been proposed (chapter 5) and validated (see chapter 6) to assess – by means of expert judgement – their impact on relevant KPIs. Together with the Ultra-Green and Time-Efficient concept documents, this document may be of interest to all airport managers and related stakeholders focusing on the competitive, sustainable and time-efficient airport of the far future.

Below, first the general assumptions are recapitulated underlying the overall development of the Cost-Effective airport concept (7.1). Next, a summary is given of the impact on costs and revenues related to a number of key cost categories (7.2). In addition, the cost and revenue structure of the Cost-Effective airport of 2050+ is given (7.3). Finally, a number of recommendations are given to support key airport stakeholders in implementing the CE airport of the far future.

## 7.1 Assumptions of the Cost-effective airport concept

The following assumptions have been taken into account when developing the CE airport concept and modelling cost structure of that airport:

- The future airport will, in-cooperation with local authorities and other transportation companies (train, bus, etc.), establish a transportation node providing intermodal connections as part of a multimodal network.. This also opens opportunities for local enterprises in retail and other service activities, which may be no longer located at the airport terminal. As a result, the airport is no longer gaining revenues from such commercial activities as renting terminal space or owning shopping venues / food courts / souvenir shops, etc.;
- Parking lots, car rent services as well as connecting public transport services are no longer the responsibility of the airport. No revenue is gained from paid parking, taxi stands and other services of these kinds. Accordingly, no infrastructure, service and maintenance costs occur;
- The number of staff assigned to primary, i.e. aeronautical activities at the airport (aeronautics) is reduced significantly:
    - Numbers of staff currently ensuring security procedures will be dramatically reduced due to employing new technologies;

  - The future cost-effective airport will no longer require a brigade of workers to handle luggage;
  - The future cost-effective airport will no longer have check-ins, thus no staff will be needed;
- Due to a reduction in turnaround time more aircraft can be served in the same time period. This increases revenue, but increases variable service costs as well;
- Due to an increased throughput more passengers can be served in the same time period then before. This increases revenue, but increases variable service costs as well;
- Maintenance costs are expected to slightly increase due to an increase in technology used at the future airport; some equipment, e.g. biometric identification system, will however substitute current technologies; also, more advanced routine check-up systems and repair systems will be available at acceptable costs;
- The depreciation cost share in total costs is expected to increase as staff will be substituted by technological solutions and advanced equipment. Investment in equipment is expected to be economically feasible, since costs of expensive technological solutions will be covered by reduced staff costs in the long run.

## 7.2 Summary of impacts on cost and revenues

This section provides a summary of the impact of the proposed CE concept and individual concept solutions on the cost and revenue structures of airports of the future. A subdivision is made to distinguish impact on staff, repair & maintenance, depreciation, materials, security, rentals, and energy costs and revenues.

### 7.2.1 Staff

Automation and the application of new technologies will require less staff dealing directly with passengers or dealing with passenger related services, allowing for reassignment of personnel to areas that are more directly linked to profitability. Adoption of many of the proposed CE solutions will however require less, yet more qualified staff. Some of the staff currently employed in positions dealing with passengers in the area of non-aeronautical services may be re-allocated to multimodal transport nodes and related service centres. This staff would not necessarily be employed by the airport, allowing for shared staff costs with other transport modes and thus a more sustainable cost structure.

### 7.2.2 Repairs and maintenance

New technological solutions are typically designed such that the need for repair and maintenance is minimized. In addition, some technology will be capable of identifying its own malfunctioning during operation. At the same time, however, highly qualified maintenance staff and operators will always be required in case of unexpected technical errors or failures.

### 7.2.3 Depreciation

As discussed in Chapter 4, a strong tendency can be discerned towards an increase in privately-owned airports worldwide. Airports in Europe used to be owned and operated by the state, but currently more and more airports are managed by contractors or privately-owned companies.

Privately owned airports tend to have a large share of depreciation and capital costs as part of their cost structure. In the light of the CE solutions proposed in Chapter 5, requiring often large investments in new technology, this share is to increase even more – mostly at the expense of staff costs.

### 7.2.4 Materials and supplies

Intelligent and technologically advanced solutions for maintenance can be expected to further proliferate in the future. As a result, the maintenance of aircraft will require less resources as more durable and easily maintainable materials will be used. Pressure to reduce the use of materials is increasing due environmental concerns and foreseeable price increases. As a result, by 2050 used materials will be recycled as much as possible and solutions requiring the least amount of valuable resources will be developed.

Other supplies, such as water, will also reduce in quantity since airports will no longer have large terminals to capture rain water and the amount of water required for technical purposes will increase.

### 7.2.5 Security

The new concept solutions proposed for security will require less maintenance and staff while providing higher levels of security. These technological advances will reduce the current cost share allocated to security measures; it will however require investment and maintenance, resulting in increased depreciation.

### 7.2.6 Rentals

The airport terminal itself will focus only on operational procedures (in case of the lean terminal scenario or the underground terminal scenario). All other services, such as shopping, restaurants, offices, etc. will be shifted to the transportation node facilities. The airport will share in the revenues of the transportation node. Airports will no longer gain revenues from renting terminal space, parking space or aircraft storage hangars.

### 7.2.7 Energy

The overall energy costs of the CE airport of 2050+ will be reduced due to a reduced number of equipment consuming large amounts of energy (check-in equipment, baggage conveyor belt, security gates, etc.). Replacing large multi-storey terminals with small, self-sustaining buildings will decrease energy consumption previously necessary to condition, light and ventilate terminals. New ANSP solutions such as remote towers or virtual cockpits will be introduced as well. Airports will be more self-sustainable; in addition new technologies for re-using energy will be introduced. However, as energy costs in future are expected to increase, energy costs will still be responsible for a significant share of the cost pie.

## 7.3 The cost and revenue structure of the Cost-Effective airport of 2050+

Given the impact on specific cost and revenue categories as outlined in the previous section, a number of changes can be expected in the overall cost structure of the CE airport of 2050+::

- Instead of accounting for up to 35 per cent of total costs, staff costs can be expected to be not more than 10-15 per cent
- Depreciation is expected to increase up to 35 per cent as airports will be privately owned and large investments will be made into both purchasing new equipment and reconstructing the airport to close large passenger terminals;
- Repairs and maintenance costs, including costs of developing and adopting complicated communication and information systems, are expected to increase to up to 20 percent as complicated technological solutions with more expensive maintenance will be introduced;
- Materials and supplies are to account up to 11 per cent of total costs, as resources required for smart technologies will be in high demand in the future;
- ITS solutions to connect airports to the public transport system will be required to ensure maximum efficiency. The costs of maintaining and constantly updating such systems might account for up to 3 percent of total costs;
- Security costs are expected to be minimal, as technology will do all the work, however some human resources will still be necessary for rapid intervention in case of a security breach; up to 1 percent of total costs should be allocated to the security.

Below, the resulting cost structure of the CE airport of 2050+ is given by means of a cost pie.

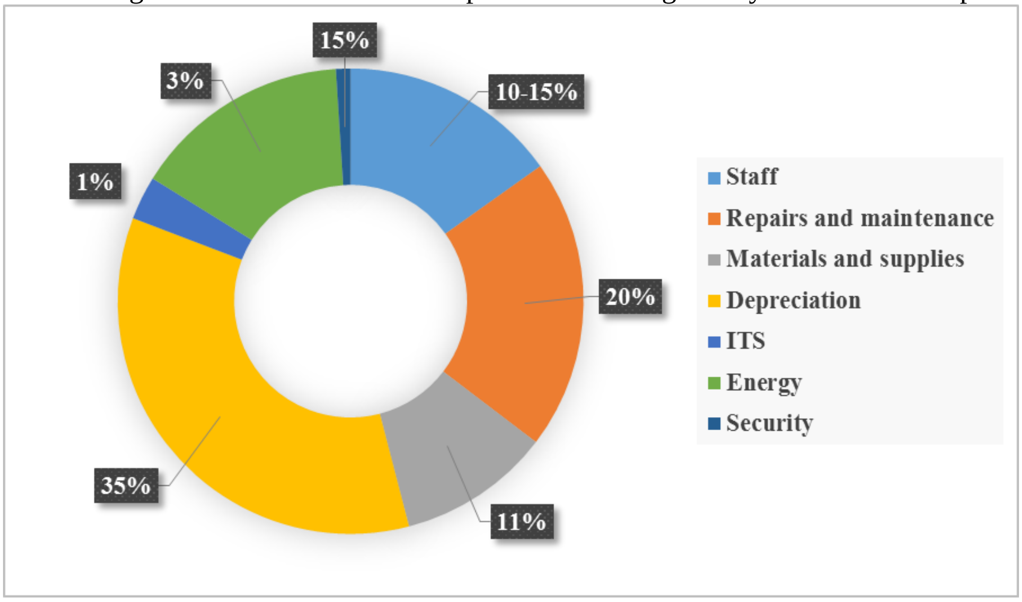



Figure 20: Forecasted cost structure of future airport

In contrast to the future cost structure, the revenue structure for the CE airport of 2050+ is too difficult to model and develop. Main reason for this is the significant variation that one encounters when studying both the aeronautical and non-aeronautical revenues of different airports. This variation is too strong to justify any general statement about the future cost structure of airport revenues. The only trend discerned is an increase in non-aeronautical revenues; this trend is already underway and can be expected to become even more important for the future due to a constant pressure from the airlines and passengers to reduce fees associated with aeronautical activities.

## 7.4 Recommendations

Based on the cost and revenue research conducted, the Cost-Effective airport model developed, the individual concept solutions created and the concept solution validation performed, a number of recommendations can be formulated. First, it has become evident that existing airports should be open for new CE solutions, technologies and processes to improve their services in the long run. These new services might imply high investment costs at the beginning but experience shows that these investments pay off in the long run, yielding lower operational costs and better opportunities to increase future revenues.

For newly constructed, green-field airports, alternative airport and terminal layout structures have been investigated. If the currently costly terminal is moved towards the city centre, allowing for e.g. high-speed rail connections between terminal and gates, then a significant cost reduction can be expected in the long-run. The city-centre terminal can be jointly owned/operated with other transportation modes, having a shared service centre part in the city and a much leaner and thus more economic airport terminal at the airport's premises. In addition, revenues may go up due to a larger number of possible customers since in this case not only air transport passengers but also many other people may use the service centre facilities.

The research on which this document reports proposes several ways towards cost-efficiency; some may require large investments, others only encourage thinking differently about sharing and/or utilizing available resources. Interestingly enough, as evidenced by the validation workshop results detailed in Chapter 6, not only this CE concept document, but also its Ultra-Green and Time-Efficient counterparts propose solutions that provide benefits in the area of Cost-Effectiveness (CE). The "Common" part of the concept solutions presented in Figure 7.2 below summarizes all conceptual ideas, both developed as part of the Ultra-Green, the Time-Efficient and the Cost-Effective airport concept, that are likely to become the most beneficial solutions for the Cost-Effectiveness of future airports:

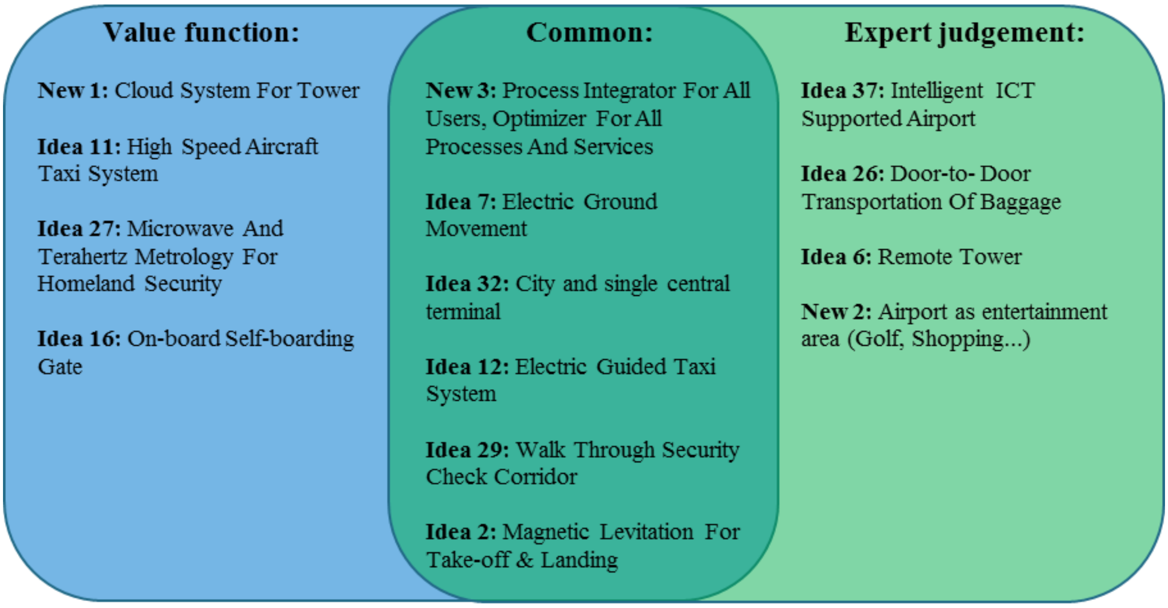



Figure 21: Conceptual ideas recommended for further investigation

These ideas are therefore the recommended solution candidates for further, more focused research aimed to make the vision of a Cost-Effective airport of the far future come true.

## Acronyms and Definitions

| | |
|---|---|
| AC / AR | - Aeronautical Cost / Revenue |
| ADS-B | - Automatic Dependent Surveillance – Broadcast |
| AIS | - Aeronautical Information Service |
| ANSP | - Air Navigation Service Provider |
| (D-)ATIS | - (Digital) Automatic Terminal Information Service |
| ATM | - Air Traffic Management |
| CAD | - Context and Architecture Description |
| CDM | - Concept Development Methodology |
| CE | - Cost-Efficient |
| C-I | - Change-Impact |
| DME | - Distance Measuring Equipment |
| EGNOS | - European Geostationary Navigation Overlay Service |
| E-OCVM | - European Operational Concept Validation Methodology |
| GAAP | - Generally Accepted Accounting Principles |
| GBAS | - Ground-Based Augmentation System |
| GNSS | - Global Navigational Satellite System |
| FIPEL | - Field-Induced Polymer Electroluminescent Lighting |
| ICT | - Informatics and Communications Technology |
| ILS | - Instrument Landing System |
| KFA | - Key Focus Area |
| KPA | - Key Performance Area |
| KPI | - Key Performance Indicators |
| LED | - Light Emitting Diode |
| LTO | - Landing/Take-Off |
| MAGLEV | - Magnetic Levitation |
| NAC / NAR | - Non-Aeronautical Costs / Revenues |
| NAS | - National Airspace System |
| NDB | - Non-Directional Beacon |
| NOx | - Nitrogen Oxides |
| O/D | - Origin-Destination (passengers) |
| PA | - Passenger Annunciator |
| PAPI | - Precision Approach Path Indicator |
| PAX | - Passenger(s) |
| PRM | - Passengers with Reduced Mobility |
| RBT | - Reference Business Trajectory |
| RNAV | - Area Navigation |
| RWY | - Runway |
| SBAS | - Satellite-Based Augmentation System |
| SBT | - Shared Business Trajectory |

| | |
|---|---|
| SESAR | - Single European Sky ATM Research (EU) |
| SWIM | - System Wide Information Management |
| TAM | - Total Airport Management |
| TD | - Traffic Director |
| TE | - Time-Efficient |
| TMA | - Terminal Manoeuvring Area |
| TO | - Take-Off |
| TWR | - Tower |
| TWY- | - Taxiway |
| UDPP | - User Driven Prioritisation Process |
| UG | - Ultra-Green |
| VOM | - Value Operations Methodology |
| VOR | - VHF Omni-Directional Radio Range |
| WAAS | - Wide-Angle Augmentation System |
| WIFI | - Wireless Local Area Network |
| WLU | - Work Load Unit |
| WP | - Work Package |

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