APPLICATION OF ENVIRONMENTAL MODELS IN THE CONTEXT OF TOTAL AIRPORT MANAGEMENT COLLABORATIVE PLANNING

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Abstract

During the last years the problem of global warming and the effects on mankind has come more and more to the public awareness. The result is that the number of environmental protection programs has been increased as well as the funding for research projects in this area. But in the field of aviation, the development of environmental concepts has not been a main focus in the past.

The Total Airport Management initiative is developed to become a future concept for airport management. As a future concept TAM needs to focus on the various disciplines, like operational improvements. One of those is the application of environmental models and the function of being environmental friendly. The intention of this paper is to show the ability to implement environmental planning within TAM, as well as applied models for such a concept.

The conclusion is that future work has to be conducted to this topic to produce a better understanding of the environmental effects due to aviation and how these effects could be minimized and taken into consideration with regard to Airport Operations.

1 Introduction

In the last couple of years public awareness has risen to the topic of environmental protection. This “movement” has also reached the aviation sector in Europe with the implementation of various environmental protection programs. The scope of this paper is to give an overview on the areas where Total Airport Management (TAM) could affect the environmental effects of an airport and how they can be measured. Furthermore it will discuss sectors where the application of environmental planning could improve the planning efficiency of an airport in regard to the environmental friendliness.

The first section will give an overview on the political background of TAM and the basics of environmental issues. Section two will introduce the topic of TAM collaborative planning and its areas of effect. The third section discusses different environmental models, which can be used to simulate emissions at an airport. The paper will end with future aspects that could be implemented in the scope of environmental modeling for TAM collaborative planning.

1.1 Development of the Idea of a Total Airport Management

As a first step in the development of the future Total Airport Management concept, the German Aerospace Center (DLR) and the EUROCONTROL Experimental Center (EEC) have developed, as a joint initiative, the “Total Airport Management – Operational Concept Document” (TAM-OCD) [1], which is fully in line with the Single European Sky ATM Research (SESAR) Operational Concept. The SESAR initiative aims to design and validate a future operational concept which enables all categories of airspace users to conduct their operations with minimum restrictions and maximum flexibility while meeting or exceeding a number of key performance targets. The SESAR initiative must also take into account the global nature of air transport and therefore be compatible, notably from a technology perspective, with similar initiatives such as NEXTGEN in the United States.

The future SESAR Collaborative Airport Planning (CAP) approach will build on the Airport Collaborative Decision Making (A-CDM) [2], framework which is currently being implemented at a number of major European airports. A-CDM enables collaborative work between all airport partners through the sharing of relevant information notably relating to aircraft turnaround milestones.[3]

1.2 Environmental Background

The environmental effects in the vicinity of an airport with all of its operations can be divided into the following three major fields:

- noise
- land use
- air quality

The focus of this paper will be on local air quality. Therefore a brief introduction into current programs to reduce the emissions and how emissions are produced will be given in the following subchapters.

1.2.2 Air Quality Programs

The Atlantic Interoperability Initiative to Reduce Emissions (AIRE) started by the SESAR Joint Undertaking (SJU) and the Federal Aviation Administration (FAA) back in 2007 aims to improve the gate-to-gate operation of transatlantic flights. One project of AIRE focuses on the surface movements of aircrafts with its optimization potential in the areas of reduced taxi-in and taxi-out times, as well as reduces engines taxiing operations. The scope of time for the AIRE optimization is the tactical phase of a flight with a range of CO_2 benefits of 190-1200 kg per flight. [4]

In February 2009, the European Union’s (EU) Directive for the inclusion of international aviation into the EU Emissions Trading Scheme (EU-ETS) for CO2-emissions came into force. From 2012 onwards, the EU-ETS will cover all flights departing or arriving in the EU. The initial allocation of emission allowances to airlines will be based on a benchmark which is calculated by dividing the 2004-2006 CO2-emissions of the airlines participating in the scheme by their transport performance expressed in revenue tons- kilometers of the year 2010. [5]

1.2.3 Pollutants and Restrictions

The trust which an aircraft needs for producing enough lift for take-off is produced by the engines by burning fossil fuels. In general this fuel is a combination of carbon and hydrogen plus additives. Beside the trust there are other effects of burning fuel, for example emissions. The following reaction scheme describes the results of an ideal as well as an incomplete chemical reaction.

$$\underbrace{C_nH_m}_{\text{Fuel}} + S + \underbrace{N_2 + O_2}_{\text{Air}} \Rightarrow \underbrace{CO_2 + H_2O + N_2 + O_2 +}_{\text{Products of Ideal Combustion}}$$

$$\underbrace{NO_x + CO + SO_x + Soot + UHC}_{\text{Products of incomplete Combustion}}$$ [6]

Due to the fact that no ideal combustion process has been reach yet, the ICAO has implemented standards to certify aircraft engines. These standards are published in ICAO’s Annex 16 Volume 2 – Aircraft Engine Emissions. The certification process describes the circumstances for the environmental engine testing as well as the maxima for the flowing pollutants:

- Unburned Hydro Carbon (UHC)
- Carbon Monoxide (CO)
- Nitro Oxides (NO_x)
- Soot

With testing an engine, the amount of emitted pollutants for each type of engines is determined and published as Emissions Indices (EI) in the ICAO engines emissions database. These EI’s indicate the amount of pollutants in grams emitted per kilograms fuel burned.

Beside the above mentioned pollutants there are additional ones that are of interests for an environmental model but they are not part of the Annex 16 Vol. 2 certification process:

- Carbon Dioxide (CO_2)
- Sulfur Oxides (SO_x)

2 Total Airport Management

Airport development plans depict more and more capacity problems due to expected air traffic growth. Often such airports are not allowed to put money into new infrastructure because of environmental and social restrictions. Another way of increasing the throughput is to optimize the airport operations. Nowadays improvements concentrate mostly on single solutions and consider short term planning. Stakeholders (e.g. Authorities, Airlines, ATC, etc.) at the airports often do not realize the impact of their actions on other stakeholders. And quite often they do not know how other stakeholders react in a given situation. These effects reduce the efficient use of the stakeholder's different resources.

The new TAM – Total Airport Management approach provides a solution for more efficient resource utilization and a holistic airport management system for airside and landside processes, based on already implemented A-CDM compliant systems.

To ensure an overall Quality of Service (QoS) of an airport to the customers and to the air transport network, TAM concentrates on the planning phases of the day of operations using the most accurate information available. This planning is performed over medium term or pre-tactical horizons. The spatial scope of TAM is the entire airport, monitoring and guiding airside and landside operations while taking into account additional information available through System Wide Information Management (SWIM) but also surrounding airports within a definite area.[3]

With TAM an environment is created wherein stakeholders are given the possibility to maintain an Airport Operations Plan (AOP). The AOP will be created through different planning systems. These consider flight plans, airport parameters, key performance indicators, stakeholder preferences, agreed goals and dynamic and static constraints.

Different implementation options will be enabled. For example, at the core of the TAM management layer will be the APOC (Airport Operation Center), which can be either a

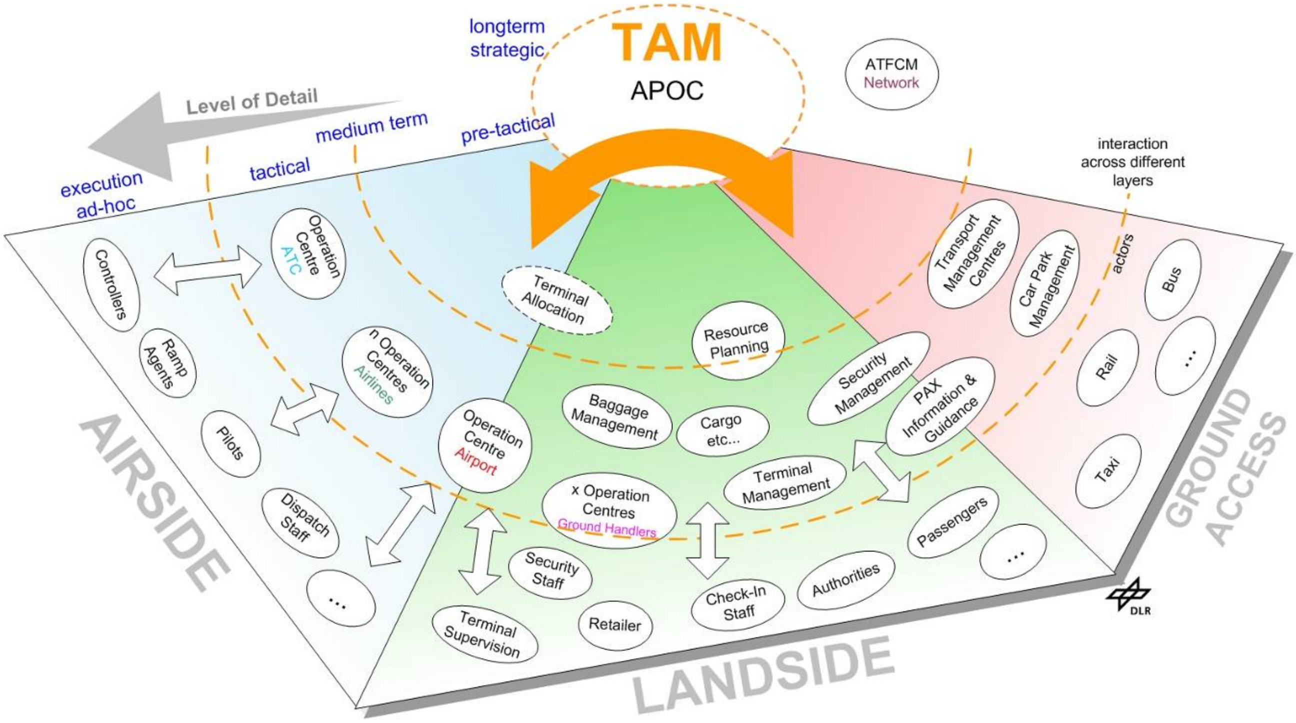

Fig. 1: Scope of TAM

centralized physical command and control room or a distributed solution, connecting stakeholder representatives by information technology solutions.

With an APOC an opportunity is given to provide the airport stakeholders with a common platform enabling the stakeholders to jointly organize and coordinate their activities under the full situational awareness of impacts of joint decisions on their own and others' operational plans.

In the APOC the representatives from Aircraft Operators, the Airport Authority, ANSP and ATFCM (depending on the size of the airport) and Ground Handling Agents will be integrated.

Fig. 2: Example of a DLR APOC

The APOC - Agents will stay in contact with their own operation centers to coordinate the required information that is passed to the central AOP computation and optimization process. The Arbitrator will moderate the decision making processes and ensure convergence.

All APOC - Agents will be provided with displays illustrating the present solution and plans for the future, indicating the parameters' settings and outlining the progress of negotiation of different tasks. Additionally, every agent is offered personalized information (e.g. in-depth information to flights of his organization).

One of the most important tools in the APOC is the Total Operations Planner (TOP), which not only computes optimized traffic flows on a more abstract level, it creates balanced arrival and departure sequences on a flight by flight event level, taking into account dozens of different parameters. Dedicated coordinated communication with tactical arrival and departure management tools guarantees an optimized tactical plan, allowing the considering of the preset computed by TOP.

Key Performance Indicators (KPI) give the agents an opportunity to measure and compare the Airport performance parameters in an aggregated view with other Airports. At the same time these indicators also serve as an input for driving the Airport in the way all stakeholders commit to. So they are incorporated in the calculation of the AOP via the TOP.

Such key performance indicators to incorporate can be:

- Punctuality (for example operating more punctual flights, means to reduce the number of flights planned out of the 15min window (according to IATA, every flight within a 15min window will be seen as punctual), but probably increasing the overall delay minutes due to less unpunctual flights but with more particularly delay)

- Queue length (keeping more aircraft on hold [e.g. arriving aircrafts are forced to fly holding patterns or departing aircrafts have to wait at the RWY] will maximize the use of resources that can be achieved – up to a certain queue length)

- Cost and efficiency (cost reduction or maximizing the efficiency of different Airport operations)

- Environmental aspects as noise or emissions

Nowadays environmental aspects in the scope of Airports mostly cope with noise. Restrictions or operational adjustments due to emissions for example from the engines of the airplanes are not considered.

Environmental awareness especially around the Airports raised in the past and a "new thinking" about environmental impacts of the air traffic came up. To fulfill the needs of the population and environmental protection the EU has started with the emission trading scheme.

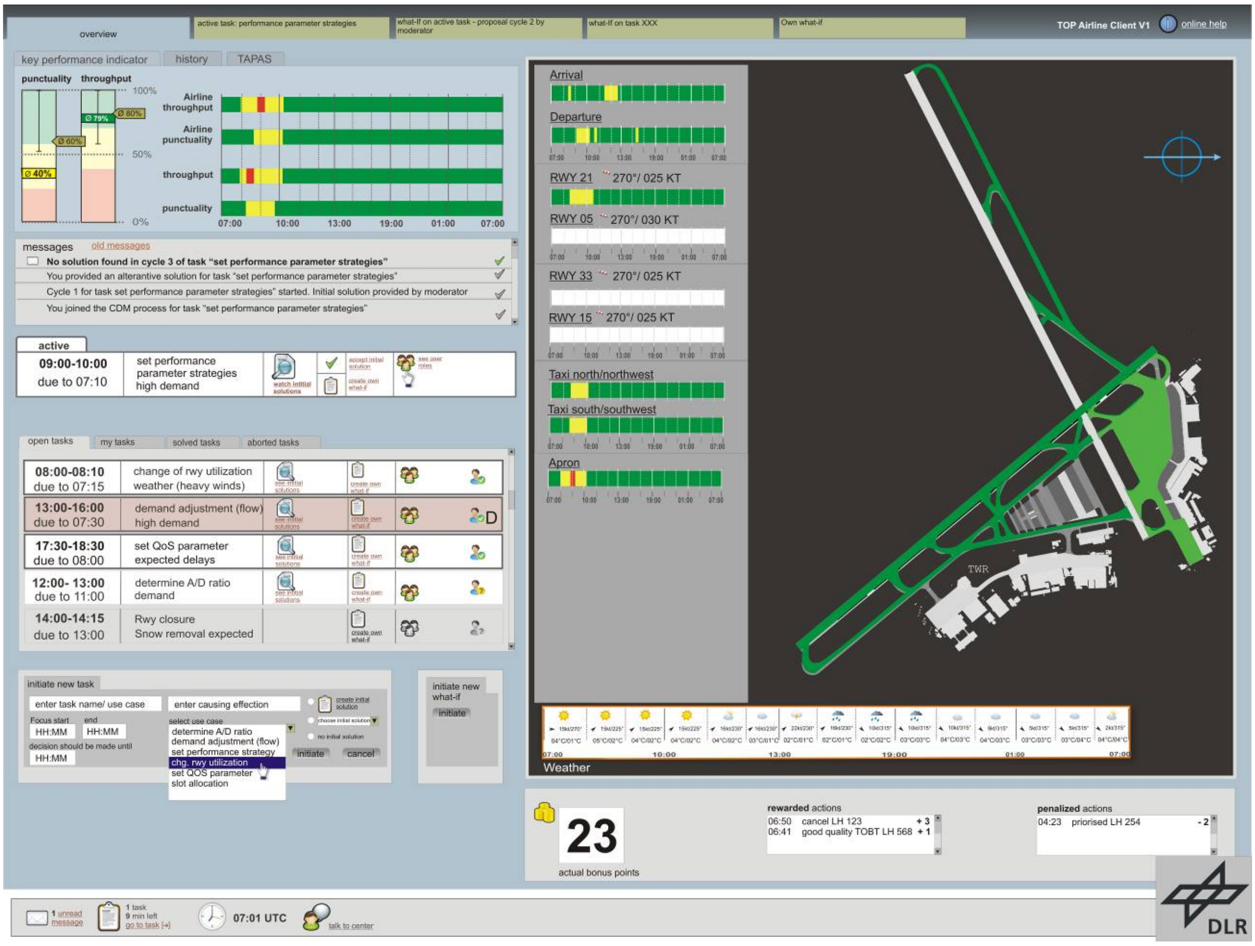

Fig. 3: Visualization of a possible support tool

Another step towards environmental friendliness has been taken by several Airports by reducing or prohibiting the use of the Auxiliary Power Unit (APU).

In the scope of TAM we will more concentrate on the KPI emission, its impact, possible ways of measuring it and the setting in different situations at the Airport.

2.1 Environmental Aspects

Most passengers on the way to their flights did already experience the smell of burned fuel at an airport. Inhabitants living in the neighborhood of an airport or working on the apron are not only annoyed by the noise of the aircraft but also by the emissions of the turbines and engines of aircrafts as well as from different ground support vehicles.

The idea of emission trading only concentrates on carbon dioxide as an indicator for global warming. But turbines of aircrafts or engines of ground equipment emit much more air pollutants with unmeasured influence on the ecology. There are already different cities in Germany, which have implemented zones with a limitation of respirable soot emission for car traffic. That causes embargos for different types of automobiles. Nowadays different filter systems are also mandatory and feasible. But the engines of aircrafts are not equipped with such filter systems reasoned by the style of the turbines.

In the Industry more and more regulations exist e.g. for power plants to filtrate the respirable dust or sulfur compounds.

On airports it will be hardly imaginable that embargos for aircrafts or ground equipment due to their emissions will be feasible because of economical reasons. But restrictions for aircraft noise already exist due to the ICAO Annex 16 Volume 1 -Aircraft Noise. It might be possible to install a similar system for different types of emissions. Through such a classification the admission to land aircrafts with a very high air pollution level could be denied or the airline is forced to pay higher fees. That means Airlines will cancel flights, substitute their aircraft fleet by modern types or pay the fees, which could be used for different environmental compensation measures.

With a categorization only according to noise it is possible to "cheat" the system. Old aircrafts with noisy turbines can be upgraded with hush kits, which do not reduce their pollution (e.g. the smoke streamer). Also a modern more quiet aircraft as the A380 emits a lot more emissions than smaller probably more noisy aircrafts do. One of the steps is to incorporate the KPI "emissions" into the Airport Planning Process. This KPI will be used to limit the immissions that would have an effect on the nearby residential areas or environmental protection areas by limiting the amount of emissions emitted by the aircrafts.

Therefore a categorization of aircrafts by their amount of emissions is necessary. With this categorization it is possible to allow or prohibit the use of aircraft types with a "bad" emissions ranking because their emissions would exceed the immissions limitation in the nearby areas, as they are mentioned above. The key factor to categorize aircrafts will be the amount of emissions in kg produced by burning one tones of fuel.

We assume that the threshold for immissions strongly depends on the weather. Wind, precipitation, temperature and the solar radiation will have an influence on the threshold and therefore the actions that have to be taken for reducing emissions. Different analyses have to be conducted to validate future models showing dependencies and the range of possible critical immissions. Such models can also help to define different graduated areas of immissions.

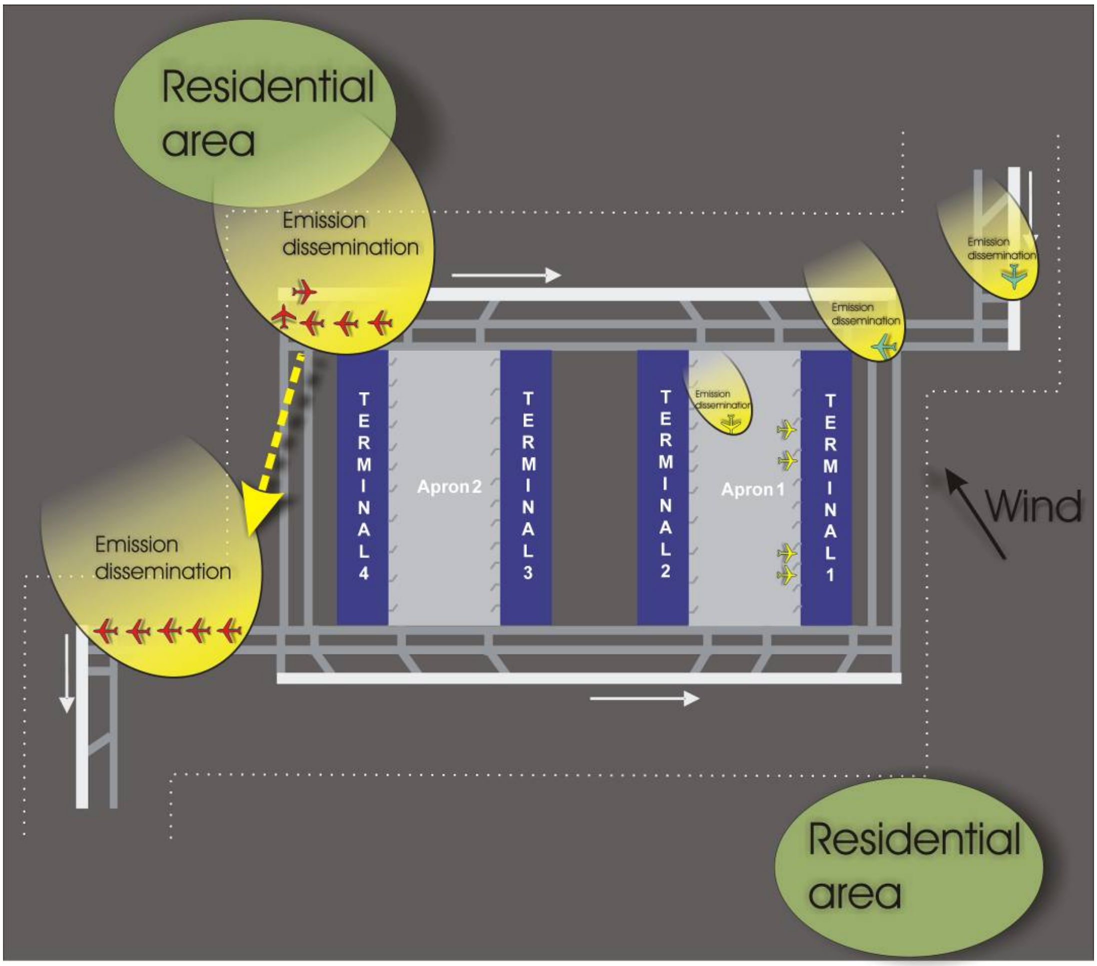

Fig. 4 Schematic distribution of emissions at an airport

In the context of TAM it is imaginable, that in a strategic time phase (up to some months in advance) a strategy will be negotiated how many aircrafts of what category are acceptable e.g. for free. More flights of that category will cost a specific fee. Due to the percentage of airline specific flights, compared to all flights, airlines have a certain number of flights "for free". For example in summer time in August due to a high solar radiation a higher influence of emissions on the environment is expected. This results in a reduction of flights "for free" operated by the airlines. The additional revenue could than be spend for compensation measures.

In the pre-tactical phase (day of operation) the AOP will be calculated and optimized incorporating the weighting of different KPIs, as mentioned before. A higher weighting of the KPI emissions may result in a minimization of taxi times with the effect that the utilization of capacities of different resources does not correspond to the optimum (reduced number of handled flights e.g. on the runway due to minimized queue lengths at the runways). At airports with more than one runway it also could result in a different utilization of the runways. As an example, due to wind the emissions from departing aircrafts on one runway strongly affect the environment in the near neighborhood of the airport. The decision will be met to let the aircrafts depart from another runway which is less affecting the environment. On the Apron not only aircrafts emit exhaust gases. Ground equipment (cars, trucks, loader, pusher etc.) pollutes the air additionally. In different analysis the effect of the emissions of automobiles compared to aircrafts will also be determined.

Different ways of optimizing the operation of ground equipment does automatically decrease idle times. Especially with system assistance for Operation Centers, the ground handler will have a better situational awareness about the status of own equipment and can save time by directly transmitting voiceless instructions.

Different analysis might also show what kind of equipment used emits most of the emissions, leading to a replacement or better utilization.

The following Chapter will describe environmental models that could be applied in the TAM collaborative planning concept.

3 Environmental Modeling within TAM

This section of this paper will describe a first approach in environmental modeling that could be applied as a source of information to enhance the APOC planning at an airport.
The scope and area of influence of an applied model will be described and the requirements and necessary information will be discussed, which should lead to an understanding of the specific characteristics of such a model, especially in the area of pre-tactical planning.

3.1 Included Sources

Every machine at an airport that is run by burning fossil fuels emits pollutants to the environment. Therefore it is necessary to get to know all sources of pollutants. Due to the theme of this paper, only sources of pollutants that can be influenced by TAM will be taken into account for the simulation of emissions.
This leads to two different groups of emission sources:

- Aircrafts
- Ground Support (GS)

The engines of an aircraft are defined to be the turbines and auxiliary power units (APU). There are all kinds of different GS, such as fuelling and catering trucks, de-icing trucks and so on. Since the area of influence of these two groups is different they should also be separated in the environmental model.

3.2 Characteristics for a TAM Environmental Model

The environmental modeling performed within the TAM context focuses mainly on the pre-tactical phase of the planning process but it can also be used to evaluate the environmental efficiency of the planning in a post-operations process. Therefore it is necessary to save all flight plans, as well as changes to them, to give the APOC agents the ability to evaluate their decision making in the aspect of environmental friendliness in a post-operations process. The post-operations results can also be used to document the CO_2 output for the ETS of aircraft operations in the vicinity of that airport.

3.2.1 Tactical Aircraft Emissions Model

On the tactical and post-operations side the environmental modeling is defined by the following flight modes for every aircraft, as indicated in ICAO's Landing Take-Off (LTO) cycle [7]:

- Approach
- Taxi-in and Taxi-out
- Take-off
- Climb-out

Whereas the vertical extension should not exceed 3000ft due to fact that the parameters of the atmosphere change with increasing altitude (e.g. temperature, wind direction and velocity, clouds).

The aircraft pollutants (AP), as described earlier, will be calculated for each mode, by the help of the following equation.

$$AP_{mode} = t_{mode} * EI_{mode} * ff_{mode} * N_{Eng} \quad (1)$$

With

- t_{mode} = time in mode
- EI_{mode} = Emission Indices for mode
- ff_{mode} = fuel flow in mode
- N_{eng} = Number of engines

The aircraft emissions inventory (*AEI*) for one pollutant is the sum of all AP_{mode} and all flights, as indicated by the following equation, whereas the total emissions inventory contains all pollutants.

$$AEI_{pollutant} = \sum flights \sum AP_{mode} \quad (2)$$

In the first application, the approach, take-off and climb-out times will be set to a constant value, as indicated in the LTO cycle. The taxi-in and taxi-out times will be variables, with real values coming from the operational system (such taxi times might be hold in databases). This will give the agents the opportunity to get a real time environmental feedback accompanied with their decision making. If the agents in the APOC do not use the environmental decision support in each and every case, they will have the option to use it in a post-operations process. Therefore every flight plan and changes to it have to be saved. The environmental post-operations metric could be used by the airlines as one part of their ETS documentation as well as by the airports for their environmental statement.

The data which is necessary for such a simulation can be provided by an A-CDM network or the ETMS on the European side or by TFMS on the US American side. Beside time nodes the aircraft type is very important because it will provide information on the engine type that it uses. By knowing the engine type, reference values for the emissions indices as well as fuel flow for that engine can be obtained from ICAO's engine emissions database.

3.2.2 Pre-tactical Aircraft Emissions Model

In comparison to the tactical environmental model, the pre-tactical model has slightly different requirements, which are mainly defined by the data that is available for this planning. The data that could be used for this type of planning is not as specific as the one that is used in a tactical planning process. The more the planning process aims into the future the less information will be available for a flight event, because no flight plan information are available. In case of ad-hoc flights, the flight plan will be filed 30 minutes prior to departure, which means that this event could not be part of a pre-tactical planning in the scope of several hours.

Since emissions for unpredictable flight events could not be calculated, the use of a flow model is applicable. This flow model consists out of an average traffic flow for an airport with an average fleet mixture in respect to time. The

usability of this flow based environmental model needs to be evaluated in the future.
Its goal is to give APOC agents the ability to evaluate their what-if probing or large scale operations constraints on the environmental friendliness in regard of operations planning.

For the time spent in taxi mode, averages will be used to determine the environmental effect for this type of operation. The other modes will be kept constant, as mentioned in the tactical LTO section, above.

3.2.3 Tactical Ground Emissions Model

Beside the emissions which were produced by flight operations, there are also emissions produced by the ground support vehicle. These emissions should be determined by a tactical ground emissions model with the goal to minimize the environmental effects produced by ground operation. This could be achieved by an optimized assignment of ground vehicles, such as busses, or a reduction in driving distance by finding the optimal way.

The parameters, which are necessary to calculate the ground emissions, are defined as followed:

- Vehicle type
- Running time of the engine
- Fuel flow
- Emissions Indices

The calculation of the pollutants (GP), which are produced by a ground support vehicle or equipment, the following equation, will be applied:

$$GP_{vehicel} = t * EI * ff \qquad (3)$$

With
- t = engine running time [s]
- EI = Emissions Indices [g/kg]
- ff = fuel flow [kg/s]

The ground emissions inventory (GEI) is defined to be the sum over all pollutants of one sort, which are produced by all ground vehicles.

$$GEI_{pollutant} = \sum GP_{vehicle} \qquad (4)$$

The total ground emissions inventory is a matrix which sums up all ground emissions inventories for each of the described pollutants.

3.2.4 Pre-tactical Ground Emissions Model

The pre-tactical ground emissions model has the same scope as the aircraft model. It should enhance the APOC agents with the ability to evaluate large scale changes in airport ground operations. An example could be the closure of a taxiway or changes in the de-icing fleet.

4 Future Aspects

One future aspect will be to add a dispersion model to the already existing emissions inventory to estimate the immissions and therefore the effect of the pollutants on the local community.
A second aspect will be the software integration of such models into the TAM collaborative planning environment, as well as the integration in the processes and the definition of a modified decision making, in comparison to today’s decision making in respect to the environmental sensitivity.
The weighting of the impact of one pollutant’s environmental effect to another one might lead to a change in the perception of certain pollutants and therefore in changes of operations to reduce these pollutants.
The last aspect in the scope of this paper is the categorization of aircrafts by the mass of pollutants and the impact of their pollutants, to introduce a simple approach of environmental classification into the TAM collaborative planning process.

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