PILOTING ATM

THROUGH PERFORMANCE

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BACKGROUND

During the past decade, all transportation systems in Europe have increasingly moved towards a more commercial way of operation. Air transportation has followed this trend, by adopting a more business oriented focus. Contributory factors include: abolition of State controlled monopolies: airlines deregulation policies and by establishing institutional changes to foster increased and fairer competition. These factors have triggered more cost and performance awareness.

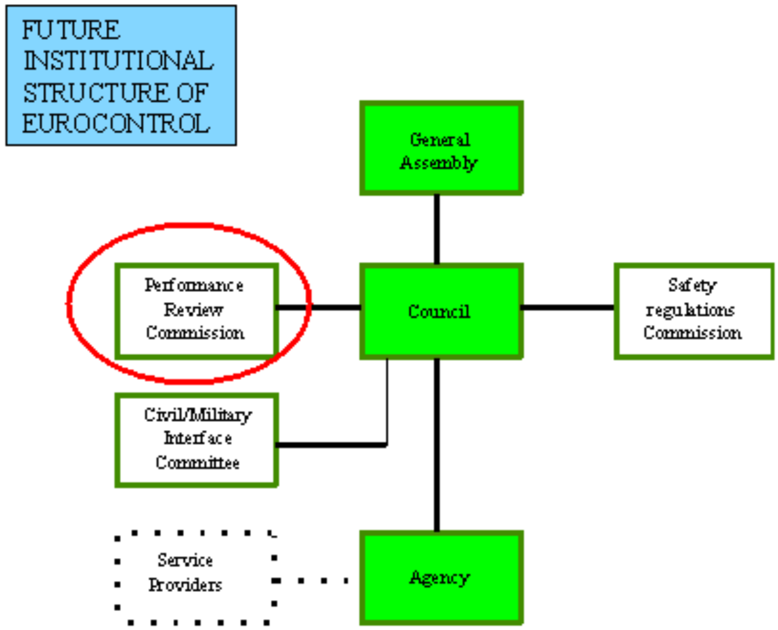
Previously, the Air Traffic Management community, (of which EUROCONTROL was and is the European coordinator and management body), was driven by the technological capabilities of its subsystems. The system definitions and development strategies were largely based on technical/engineering based objectives.This is no longer the case. A cost/benefit assessment of the system is becoming a key driver in strategy definition and system improvements.

Therefore the overall cost of the system and its level of performance must be correctly measured in order to assist the decision making process.
During the summer of 1995, EUROCONTROL, embarked upon the definition of high level strategic performance indicators. This initiative had full cooperation from the member States of the European Civil Aviation Conference (ECAC) and the organizations representing the users of the ATM system (airlines, charter companies, general aviation). The purpose of these indicators was to provide senior management with a clear, meaningful and well defined view of the past and current performance of ATM, to be used as an essential element for their future planning and the specification of short term and long term objectives.

By using and integrating several data sources, a stable and clearly defined set of consolidated indicators will quantify or qualify the performance and the costs of the European ATM system.

These indicators were the initial framework to constitute the common basis shared by all ATM partners permitting to assess. The indicators shall allow to assess the European ATM system, and to compare its performance with other ATM systems. They would as well enable benchmarking between European ATM providers. In addition, they would be the base−line from which the effects of improvements could be measured.

This performance driven approach was basically confirmed during the last meeting (14.02.97) of the Transport Ministers of the 35 European states belonging to ECAC. During this meeting, the future institutional structure of EUROCONTROL was agreed.



Under the auspices of a General Assembly, and the authority of the Council, a high level Performance Review Commission will monitor the overall performance of the Air Traffic Management System in its broadest definition (i.e. Gate to Gate) and will ensure proper economic regulation of the various service providers.

All air transport partners will be involved in the Performance Review System, including in particular :

- Governments and National Administrations ,
- the ATM users (including commercial airlines, general aviation and military),
- the ATM service providers,
- a representation of the matters of public and social concern (e.g. environmental issues),
- a representation of the staff active in the air transportation field,
- as necessary, aviation industry and aircraft manufacturers.

All Performance Indicators must be meaningful to all involved and their use must be easy and efficient. This is why Strategic Performance Indicators must be different from the more detailed technical information already available through the existing technical indicators. However, consistency and compatibility in use of the two types of indicators must be ensured.

1996 ACHIEVEMENTS

An initial set of Performance Indicators was developed in 1996, using data available in EUROCONTROL (CFMU and CRCO), with assistance from IATA for the airline cost information. These indicators covered en−route operation only, and, although contacts were established with ATM providers and ATM users, no full coordination had taken place. Further cooperation is necessary to validate the final set of indicators.

These Strategic Performance Indicators measured ATFM delays as the result of a lack of capacity, indicating the inability of the system to accommodate traffic demand, bearing in mind that ATM is constrained by the necessity to maintain an appropriate level of Safety and environmental concerns.

The cost of increasing capacity has to be weighed against route charges (cost of investment and cost of operating ATM), the cost of delays and other external costs for aircraft operators (longer flight routes, non−optimal profiles, etc.).

- Demand (past, current and forecast) was measured against the size of aircraft and the duration of the flight. Other criteria will be introduced in future versions (e.g. % of business passengers, charter flights, etc.). A better awareness of the demand and its characteristics will enable targeted decision making.
- Delays can be caused by several factors (e.g. weather, technical failure, strike). Previously, only ATFM delays were considered then. Work is underway in the Centre for Operational Delays Analysis (CODA) group to identify other causes of delays. The outcome of this work will be integrated in the subsequent sets of Performance Indicators.
- The percentage of flights delayed, and the average delay per delayed flight were shown. Delays were initially sorted in recurrent and non−recurrent ones. The principle was that recurrent delays were susceptible to management action and non−recurrent delays were more likely to have been unexpected events.
- Delays were considered day per day on average. It was interesting to note that, although military activity was lower and flexible use of airspace is more systematic during weekends, the percentage of flights on time was lower and the average delay per delayed flight was higher.
- The ATC units identified by the CFMU as the sources of regulations were graphically depicted, with the proper sentences highlighting the present limits in comparing ATC units, due to a lack of information on traffic and airspace complexity.
- Internal costs were presented as the en−route charges per country, sorted in investment and operating costs. The above comment on the limits of comparisons applied here as well. The evolution of en−route ATM charges showed a slight decrease as from 1994 onwards.
- External costs were calculated (with the helpful assistance of IATA) as cost of delays and cost of additional flight time:18.5 ECU per minute of delay on the ground; 32.3 ECU per minute of flight).
- Safety and environmental issues were indicated by the number of AIR PROXimities and the amount of tons of fuel burnt uselessly. Additional indicators are required in these fields.

LESSONS LEARNT

During this initial development of Strategic Performance Indicators, the following points were identified :

- The meaning of words and concepts must be clearly defined before any attempt is made to measure "performance". This is particularly true in a multinational, multi−cultural and multi−lingual environment such as Europe where even simple words like "traffic demand" can be interpreted differently (e.g. unrestrained demand, flight plans filed, actual flights, , etc.).
- Data were and are available to support performance Indicators, but are sometimes difficult to handle. In effect, is too much data to be usefully and meaningfully presented to senior management without a risk of over−complexity or information overload. On the other hand, data and information are scattered amongst many partners, airlines, international bodies, representative bodies, service providers and national administrations. Although full cooperation has been the rule, reviewing and gathering the appropriate information is a demanding and long process.
- There is a danger of producing Indicators as a result of the information available without pondering valid questions :e.g. How can Management use this Indicator and is it based on the best data source.
- Thorough attention must be paid to the stability and common use and understanding of the defined Indicators.
- Yearly, monthly, daily comparisons assist the decision making process.
- It is very difficult to compare cost performance between geographical locations. It can be expected that complicated airspace with complex traffic patterns is more expensive to manage than simple

areas with low traffic. But these relationships are not yet fully understood and are difficult to model.
- Developing Performance Indicators triggers new ideas and perspectives. The challenge leads to a better understanding of ATM services provision, and initiates a positive feedback loop between users and providers.

PLANS FOR FURTHER DEVELOPMENT

The existing set of indicators has proven to be stable and maintainable. The initial indicators covered the period April 96 to July 96 (from start of full CFMU operations until the first production date.) A second production stage was prepared in November 96 and the data from August to October 96 were added without any problem, which confirmed the stability and reproducibility of the initial set.

The plans for further development are two−pronged.

Firstly, the existing set of indicators will be validated with ATM providers and ATM users, and must be augmented and upgraded to its final content. In this process, the identification, gathering and use of data will be essential, both inside EUROCONTROL (e.g. CODA, CFMU, CRCO) and amongst partners (e.g. ATM users, airports, ATM providers, governments and national administrations etc.). Particular attention will have to be paid to the approach and airport phases of the flight, in the "gate to gate" analysis of ATM.

During an ad−hoc meeting on Performance Indicators which took place on April 3rd 1997, the following was confirmed regarding the use of Performance Indicators at a strategic level :

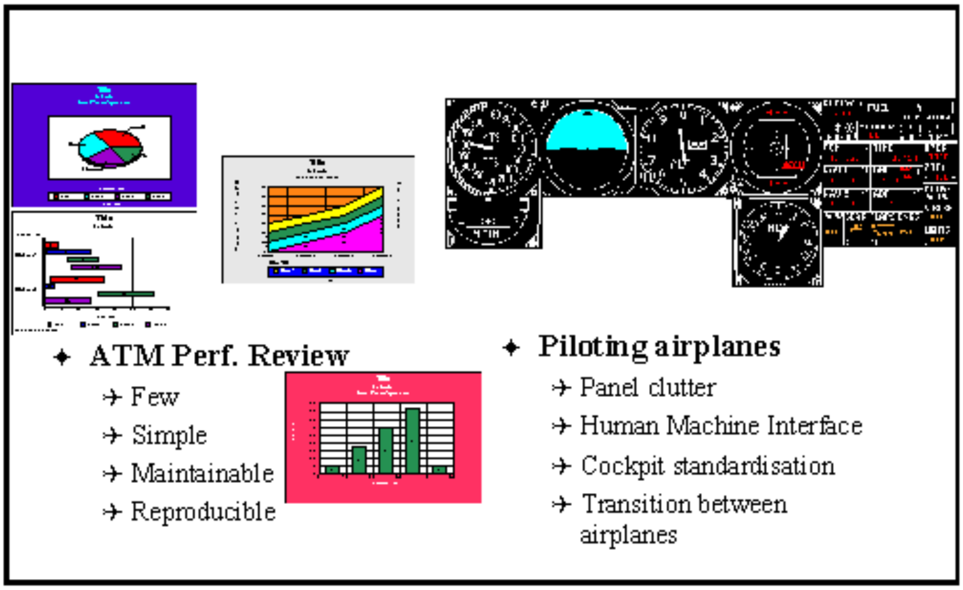
Performance Indicators are a part of the Management process

- they must have a purpose
- they are not a scientific exercise as an end in itself
- they allow delegation of responsibility and accountability

Performance Indicators must be designed in a top−down approach

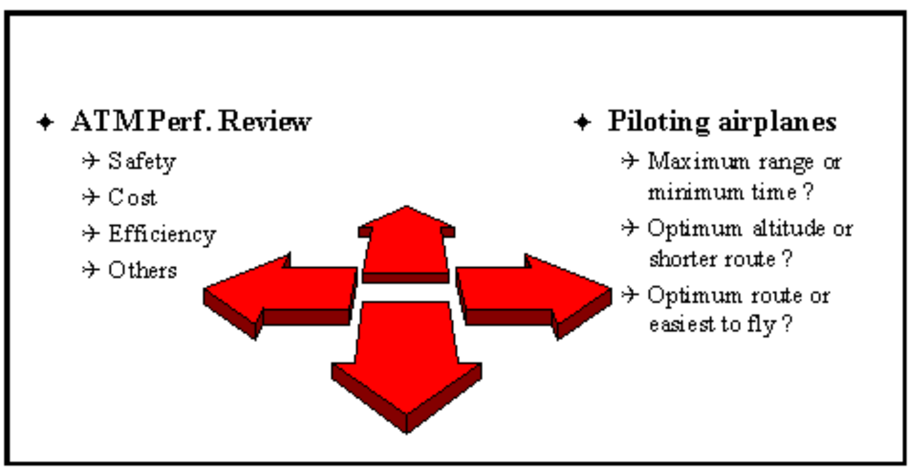
- one must identify the strategic results areas
- one must define objectives for each area
- one must choose the appropriate indicator(s)
- one must check data/information availability, validity and quality
- one must manufacture indicators

The continued operation of ATM service provision and its future development will be driven by performance related goals and a commonality of measurement sensitive to the needs of all involved



Secondly, as cost/benefit considerations are essential to the decision making process, it is not sufficient to measure current performance and to assess it against past performance.

A balanced approach will be a key to success. Estimating future performance becomes fundamental in this process.



For that purpose, it is necessary to define a limited number of Strategic Management Options, covering flow management aspects (such as "what would happen if capacity stagnates and traffic increases ?"), investment aspects (such as "what would be the effect on service of a principal investment ?") and operational/technical aspects (such as : "what would be the benefit of an overall European radar separation minimum of 5NM?").

Modeling these and other ATM scenarios and projecting the Performance Indicators 5 to 10 years ahead in simulation , will permit a valid and coherent comparison of the alternatives and will support the decision−making process.
The methodology and a first set of scenarios were defined in a project called Future ATFM Profile (FAP), the first results of which are presented below.

The Future ATM Profile

In 1996 the EUROCONTROL Experimental Centre launched the Future ATM Profile (FAP) as a research activity in support of the Performance Indicators. The FAP objective is to build up a methodology to project the performance indicators into the future, and to assess the consequences of strategic ATM options. The methodology will be used by the Performance Review Commission (PRC) to propose target Performance Indicators and make recommendations to the Council to improve ATM performance in Europe.

This part of the paper introduces the FAP methodology and demonstrates what can be done, depending on which kind of data and functionality is available, and what the potential benefits would be. The findings and conclusions presented in this paper are abstracted from the initial FAP results. These results have not yet been fully validated with all relevant Air transportation partners. They are therefore a basis for discussion and do NOT represent any official statement.

The ATM System − Users Point of View

The projection of Performance Indicators into the future requires simulation of the whole ATM system including the interface to the airspace users.

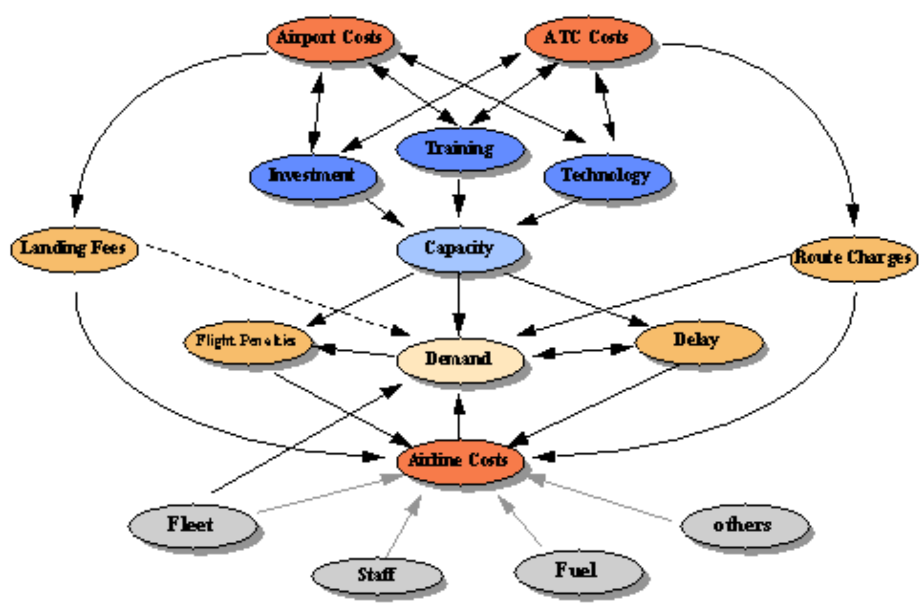


Figure 1: Influences in ATM system

The FAP methodology provides a set of linked models capable of simulating the major elements of the ATM system. These models allow simulation of future system behaviours and the anticipation of future system performance as a result of current or foreseen actions (pro−actively).

The FAP model set consists of:

- macroscopic ATFM simulation tools (TACOT and AMOC/CASA),
- an analytical Airspace and Capacity analyser (CIM)
- and the ATC simulator RAMS

Future Scenarios

FAP permits simulation of a limited number of "what if" scenarios, and displays several snapshots of the Performance Indicators at different moments in time (e.g. 2001, 2006).

At present, four flow management scenarios have been selected (technical and investment scenarios will be developed later):

- "do nothing"
  (capacity stagnates at 1996 level, traffic growth as forecasted)
- "not worse", "as before"
  (total ECAC delay stagnates at 1996 level; 1996 delay distribution throughout ECAC)
- "not worse", "delay equity"
  (total ECAC delay stagnates at 1996 level; evolution in the direction of even delay distribution)
- "no delay"
  (capacity/demand ratio is so high that flow regulation is not necessary or delays are negligible)

FAP identifies the geographical and functional causes for delay problems, has a closer look at these areas and determines the actions, or cluster of actions, for improving the situation.

Scope

The projection of the performance measurements is performed on:

- the whole ECAC area

including:

- air traffic control centres and airports
  (65 ACCs, 72 airports)
- Air Traffic Flow Management issues (CFMU slot allocation procedures)
- airport scheduling issues

simulating:

- present and future traffic volumes
  (1996, 2001, 2006)
- regional characteristic traffic growth, based on EUROCONTROL−STATFOR forecasts

Methodology

FAP combines macroscopic ATFM and microscopic ATC simulation philosophies to cover all the geographical and organisational aspects of ATM within the ECAC area.

Three simulation levels are identified (see figure below):

- Macroscopic analysis of the overall ECAC area using AMOC/CASA to identify bottlenecks and delays (for present and future traffic volumes)
- Airspace classification based on complexity (using CIM++) and equipment sophistication (using EUROCONTROL CIP data)
- Microscopic analysis of representative airspace types (using RAMS) with respect to workload and capacity (evaluating ATM actions and their impact on workload and capacity)

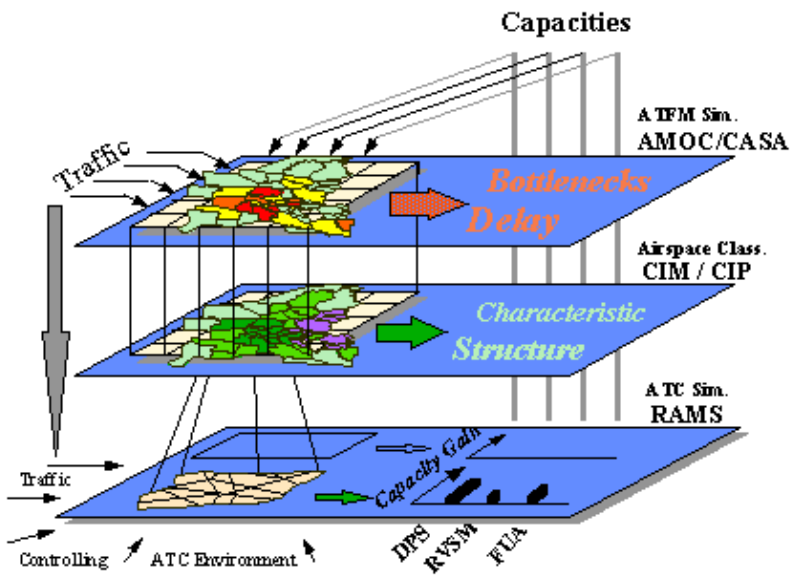


Figure 2: FAP combined ATFM&ATC Simulation Methodology

The uppermost level represents the macroscopic ATFM simulation. FAP uses traffic (demand) and capacity data recorded by the CFMU as input data for the EEC ATFM model AMOC. AMOC identifies the flights subject to ATFM delays and the Air Traffic Control Centres which are the root causes for the delay. ACCs causing a particular high amount of delay are considered to be bottlenecks.

In the second level, the bottlenecks will be classified into 4 different classes based on the parameters:

- complexity (using the CIM++ analytical model)
- equipment sophistication
  (using EUROCONTROL CIP data)

In the third (microscopic) level a representative airspace of each of the 4 airspace classes will be analysed using the new EUROCONTROL ATC simulator RAMS. FAP simulates the implication of several ATM actions (FUA, RVSM, DPS etc.) and catalogues their impact on capacity. The new capacity figures will be fed into AMOC (back loop) to estimate the benefit of the ATM actions in terms of delay reduction.

Air Traffic Flow Management Simulation

The EUROCONTROL ATFM Modeling Capability (AMOC) is linked to the CFMU Computer Assisted Slot Allocation (CASA) algorithm. This allows ATFM simulation with good coherence to the CFMU operational principles.

ATFM simulations are based on three types of input data:

- configuration (applied sectorisation and regulations)
- declared capacities (for sectors and airports)
- traffic demand (including routes and flight level restrictions)

AMOC identifies the sector and airport loads and the flights regulated by ATFM delays. AMOC allows three methods of iteration:

- configuration and/or capacities can be modified to achieve a given system load (FAP uses this option to identify the need for future regulations)
- capacities can be modified to achieve a given delay (FAP uses this option to identify the capacities needed to cope with future traffic volume at current delay levels)
- routes can be modified (which modifies the demand) to minimise delays (FAP uses this option to identify the impact of rerouting on future traffic samples)

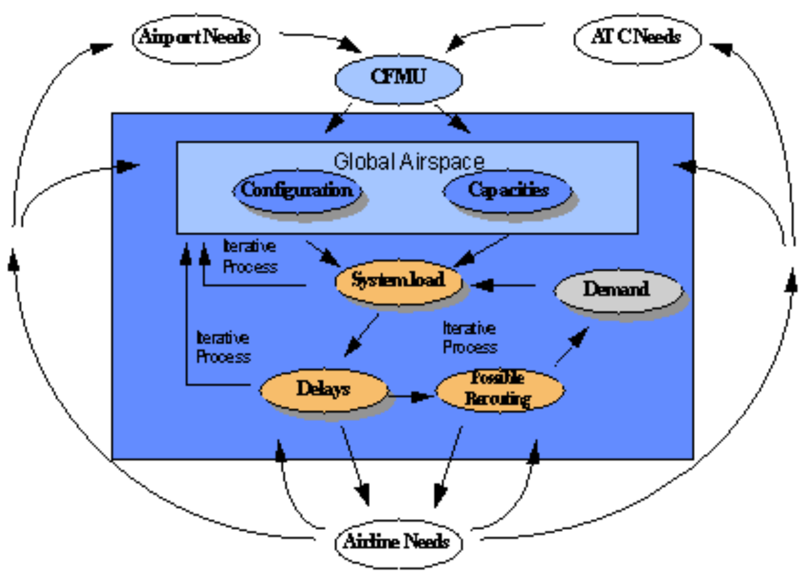


Figure 3: AMOC: Air Traffic Flow Management Simulation

FAP ATFM simulation is based on:

- sector/centre regulations as these will gradually replace flow regulations

Regulations assume

- maximum capacity (the maximum identified number of open sectors)

Validation

- AMOC simulation set up has been validated against the operational CFMU TACOT system.

ATM Bottlenecks and Capacity Shortfalls

The results of the ATFM simulations give a macroscopic overview about the current and future ATM system performance throughout Europe. They shall assist the decision making process for future ATM strategic choices providing answers to questions like:

− Where can we expect ATM bottlenecks in the future (geographically, air/ground, upper/lower airspace)?
− What are the capacity shortfalls, currently and in future?
− When do we have to act?
− What are the consequences for other ATM units?

The following chapters contain samples showing what kind of information FAP can provide, how they could be analysed and which kind of conclusions could be drawn.

Figure 4 shows what order of magnitude en route delays would reach in 2001 if capacities stagnate at 1996 level (Scenario "do nothing").

The forecasted 24% traffic increase within 5 years would result in an increase of the en route delays by a factor of 7 to 8.

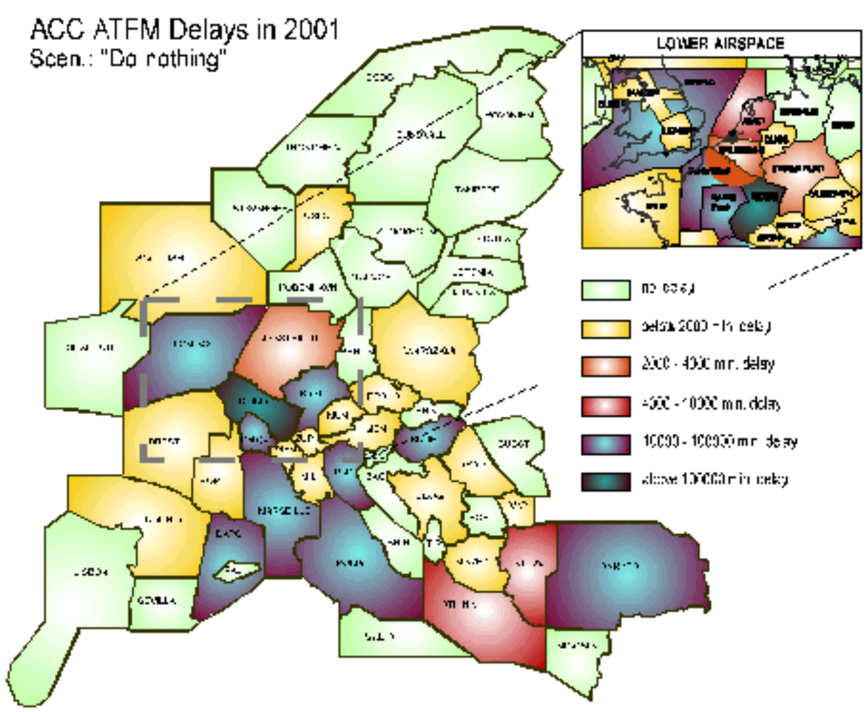


Figure 4: En route ATFM delays in 2001 (Scenario "do nothing")

Most of the ACCs will cause no or moderate delays. The minority of large delay producers (mainly located in West and Southern Europe) cause 90% of the total en route delay. They represent less than 15% of the ECAC ACCs.

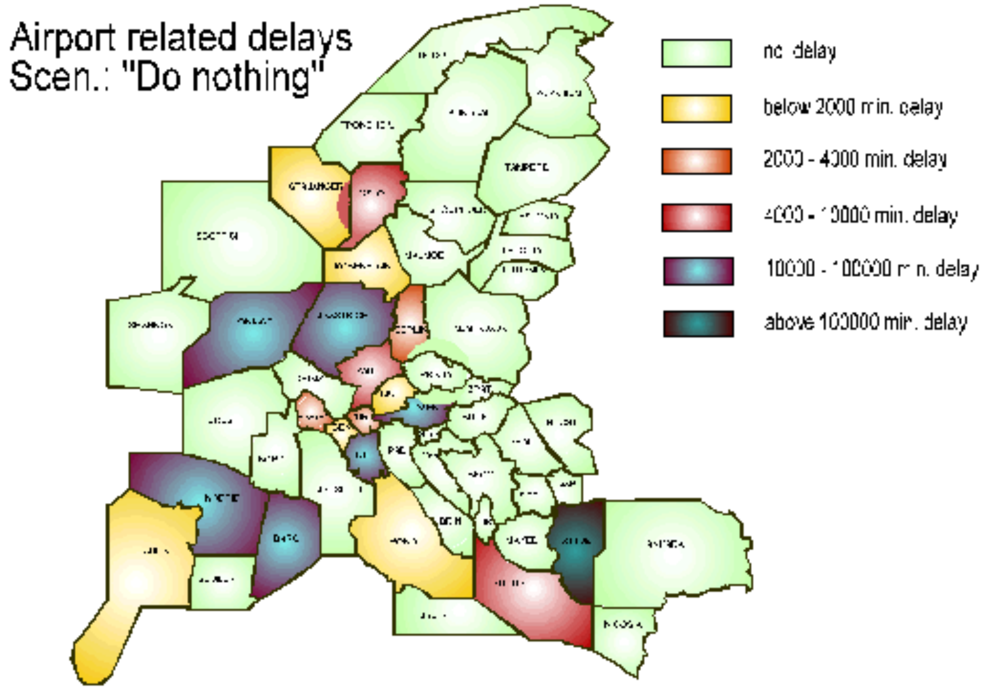


Figure 5: Delays due to airport capacity shortfalls in 2001 (Scenario "do nothing")

The same situation on the airport side. Figure 5 shows the delays due to airport capacity shortfalls located to the corresponding upper ACCs (2001, Scenario "do nothing").

The forecasted 24% traffic increase within 5 years would result in an increase of the airport related delays by a factor of 6 to 7.

As with the ACCs, most of the airports will cause no or moderate delays. The minority of big delay producers cause 98% of the total en route delay. They represent less than 20% of the 72 APATSI known airports.

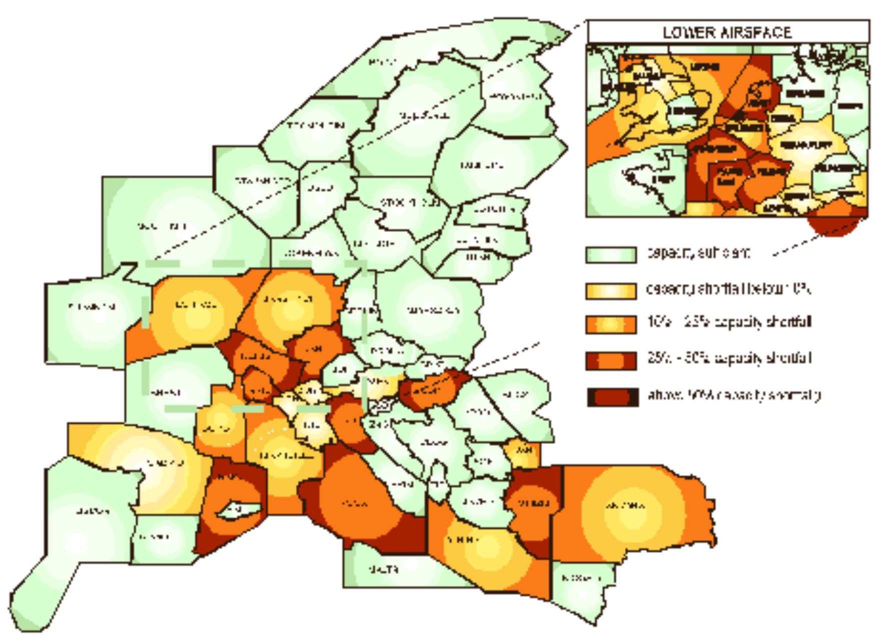


Figure 6: En route capacity shortfalls in 2001 (Scenario "no capacity driven delay")

Figure 6 shows the capacity increases necessary to reduce the capacity driven delays to zero. The remaining delays (about 30% of the 1996 ATFM delays) is due to microscopic traffic smoothing. If validated, these results should be taken into account in strategies for future ATM.

The 70% reduction of the delays at increasing traffic demand could be achieved if 10 out of 65 ACCs increase their capacity by more than 25%. 16 ACCs would need a capacity increase between 0 and 25%. The remaining rest of 39 ACCs seems to have sufficient capacity for 2001.

Delay Curves and Network Effects

It is generally assumed that the sensitivity of delays to capacity shortfall is high. And the significant delay increase shown in the 2001 "do nothing" scenario is not a real surprise. But the whole function of the delay curve as a result of the European capacity network, the forecasted traffic growth and pattern is still unknown.

The following charts provide a first insight into the European delay curves computed at three traffic levels representing 1996, 2001 and 2006 traffic levels.

Figure 7 shows how delays rise up under 1996 network conditions. The curves distinguish between delays due to airport and en route capacity shortfall. The upper black curve represents the total sum of delays.

The curves show that the sensitivity of delays increases with the demand and the capacity shortfall. They also show that airports produce more delays than ACCs (around twice as much in 1996).

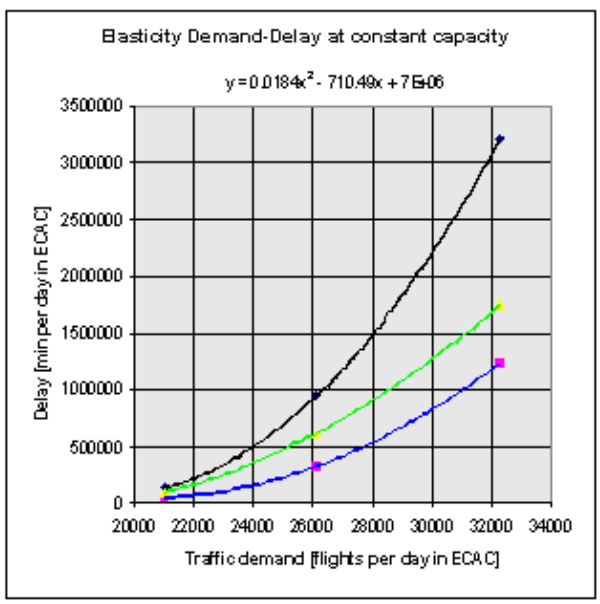


Figure 7: Total airport and ACC related delay in Europe (21/06/96)

But this could change significantly if the network capacity changes in future. The delay curves above represent 1996 network conditions and do not allow interpretation at different network condition: e.g. the evolution of delays if airport or ACCs, increase their capacity unilaterally.

It is the nature of network effects that they are difficult to forecast since all parameters are subject to future changes and each parameter in combination with others can lead to a significant change to the results. Surprises could be avoided if these kind of network effects were understood.

With Figure 8, a first approach towards this understanding of the delay network effects is given. The figure shows how delays would rise up if capacity shortfalls en route are solved and the airport capacities stagnate and vice versa.

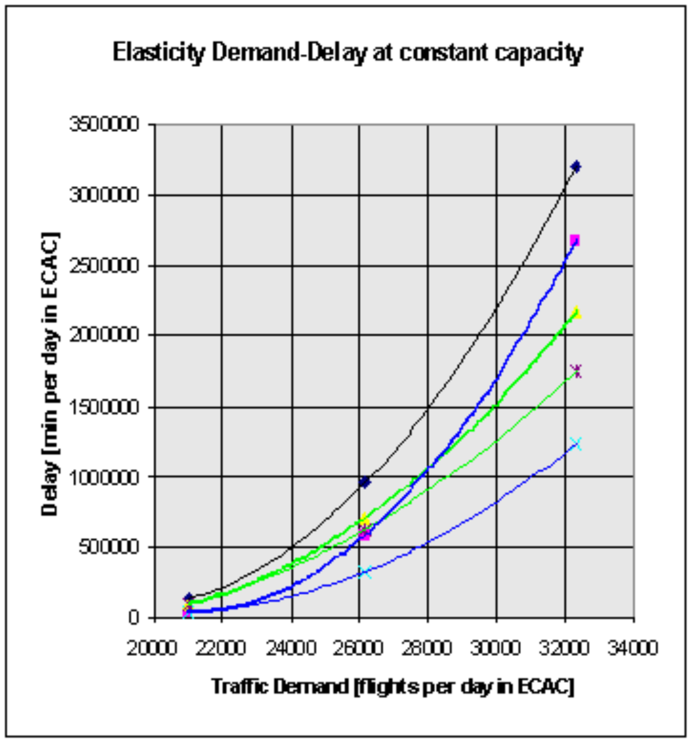


Figure 8: ACC related delays without protection by airports
Airport delays without protection by ACCs

As delays rise up, network effects will have an increasing influence. Capacity shortfalls at airports protect ACCs and ACCs protect the airports (the sum of potential airport and ACC delays does NOT equal the total network delays).

The potential delays without network protection of on or the other (ACC or airport) show a significantly higher increase for ACCs than for airports. This is because each extra flight will at worst cause extra loading at 2 ECAC airports whereas more than two sectors can be involved at the ACC.

Consequently, the network protection of airports towards ACCs is higher than that from the ACCs towards airports.

We conclude, therefore, that network effects can have a significant influence on delays. It also appears that the strongest delay producer is not necessarily the best candidate for capacity improvement.

Operating at Minimum Costs

It is known that delays represent a significant part of the indirect flight costs. It is also recognized that delays due to capacity shortfalls are one possible consequence of non−sufficient ATM service. Therefore, the real costs of the en−route ATC service and the airport service (from the airline point of view) include route charges, landing fees AND the indirect costs such as delay costs and cost for inefficient flying. Minimum costs are achieved at the point where the Total costs, the sum of capacity AND indirect costs are lowest.

Figure 9 shows, how the total costs for the airport and en route ATC service is influenced by the delays resulting from various capacity/demand ratios (shown for all delay causing ACC and airports).

The capacity cost curves are estimations based on CRCO and IATA cost figures. The delay costs are based on the EUROCONTROL estimation: 18.5 ECU per min. delay.

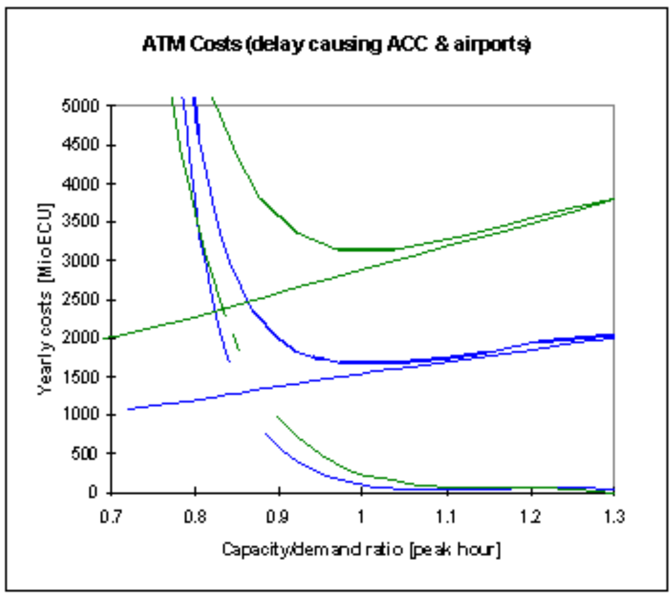


Figure 9: Airport and ACC costs versus capacity/demand ratio
(Total costs = Capacity costs + delay costs)

Some observations:

- Delay costs become a significant factor of the total costs at capacity/demand ratios lower than 0.9
- ACC and airport related delays rise up at comparable capacity/demand ratios
- Airport capacities are more costly than ACC capacities

Possible conclusion:

- Delays produced by ACCs can be reduced at lower costs than those produced by airports.

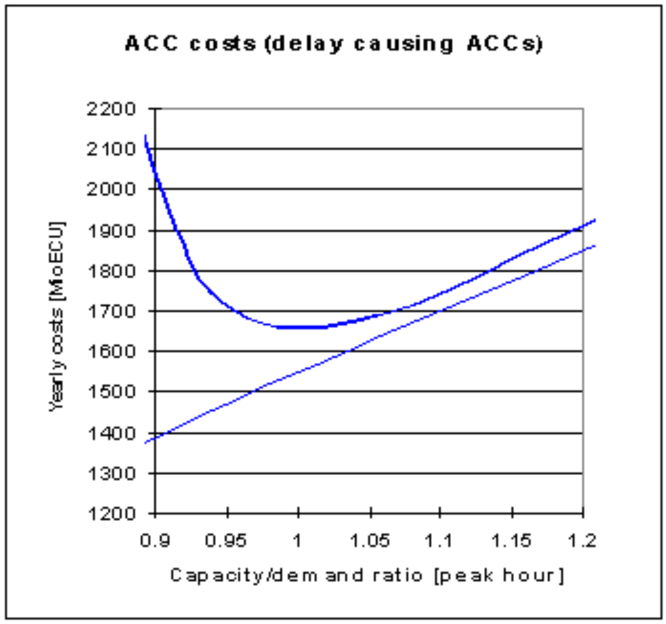


Figure 10: ACC costs versus capacity/demand ratio
(Total costs = Capacity costs + Delay costs)

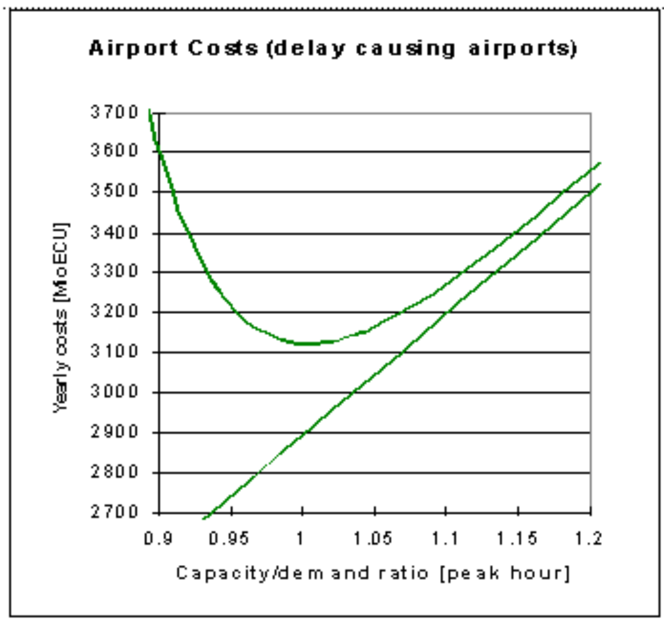


Figure 11: ACC costs versus capacity/demand ratio
(Total costs = Capacity costs + Delay costs)

Figures 10 and 11 show the minimum cost areas for ACCs and airports taken from figure 9:

- ACCs operate at minimum total costs when their peak capacity is equal to or slightly higher than the peak demand. The slope at higher capacity/demand ratio is significantly flatter than at lower capacity/demand ratios, due to the relatively low en route capacity costs.
- Airports operate at minimum costs when their peak capacity is equal to the peak demand. The total airport cost curve shows almost the same steep slope at lower and higher capacity/demand ratios.

Exceeded capacity is almost as expensive as non−exploited capacities.

Cost effective En Route Strategy:

En route capacity should always satisfy the demand (no delays due to capacity shortfalls). However, the flat slope at higher capacities show that orientation towards reasonably higher capacities might be recommended to cope with sudden demand peaks. Short term traffic peaks should be handled with a more flexible capacity planning (e.g. flexible sectorisation).

Cost effective Airport Strategy:

Airports should orient their capacities as precisely as possible at the peak hour demand. Capacity should be adjusted continuously to the demand in several smaller steps, bearing in mind that non−used capacities are almost as costly as capacity shortfalls. Short term traffic peaks might be smoothed with a flexible pricing policy.

This is the theory:
The costs curves show that cost effective airport capacity planning is more constrained and thus needs more flexibility than en route capacity planning.

And this is the practice:
Flexibility in capacity planning is far higher at ACCs (sectors can be grouped or closed) than at airports (environmental issues, infrastructure constraints etc.).

It appears to be that compatibility of theory and practice is rather limited. A possible conclusion could be that longer term ATM strategies should aim at improving conditions to operate at cost optimum operating points. Some topics could be

- improve quality of planning parameter (traffic forecast etc.)
  - action EUROCONTROL, national air navigation services
- increase flexibility of capacity planning
  - action air navigation services, airports
- improve exploitation of non used capacities
  - action Scheduling Conference, CFMU
- smooth traffic in strategic and tactical time horizon using price policies where possible
  and delays just as a last possibility
  (price policy => flow back to the ATM unit => cheaper than delays)
  - action airports, Scheduling Conference, CFMU
- priority traffic smoothing according to the (more costly and less flexible) airport capacities
  - action CFMU
- move from the adjustment of the demand according to the en route capacity to the adjustment of the en route capacity to the (airport driven) demand
  (giving tactical advice to the ACCs where and when capacity is needed)
  - action CFMU

Airspace Classification

We assume the bottlenecks and their influence on delays and costs is known. We also know the regional capacity targets to meet the global ATM strategy. But how to go there? Can we further split sectors, build new runways? What are the alternatives? Under what conditions could they increase capacities and what are the costs?

The ECAC area has a wide range of traffic complexities, ATM systems and procedures. The achievement of capacity targets requires consideration of these differences. FAP classifies the 65 ECAC ACCs into 4 airspace classes based on the parameters:

- complexity
- equipment sophistication / level of automation in provision of ATM

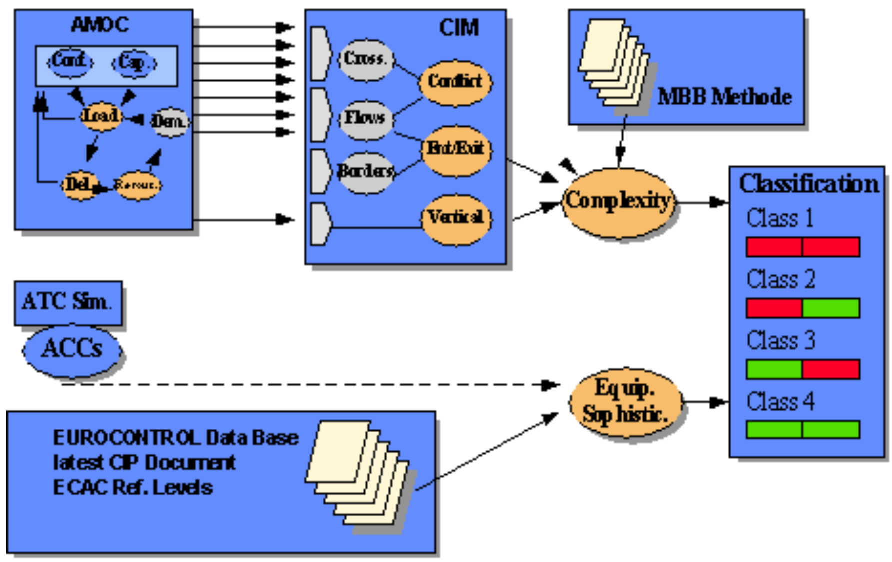


Figure 12: Airspace Classification

Complexity indicators are calculated by the EUROCONTROL analytical model CIM++ (**C**apacity **I**ndicator **M**odel). CIM assumes complexity to be composed of:

- vertical traffic complexity (cruise, climb and descent)
- horizontal traffic complexity (entry/exit points, crossing points)
- conflict probability

Equipment sophistication is categorised based on the FDPS functional level using EUROCONTROL CIP data (**C**onvergence and **I**mplementation **P**rogramme).

Based on complexity and equipment sophistication the ECAC ACCs are classified into the four classes below:

- high airspace complexity & high level equipment
- high airspace complexity & low level equipment
- low/medium airspace complexity & high level equipment
- low/medium airspace complexity & low level equipment

Each of the four airspace classes is then analysed using the new EUROCONTROL ATC simulator RAMS.

How to meet the Capacity Targets

FAP uses the Reorganized ATC Mathematical Simulator (RAMS) to identify potential key factors for ATC capacity improvement.

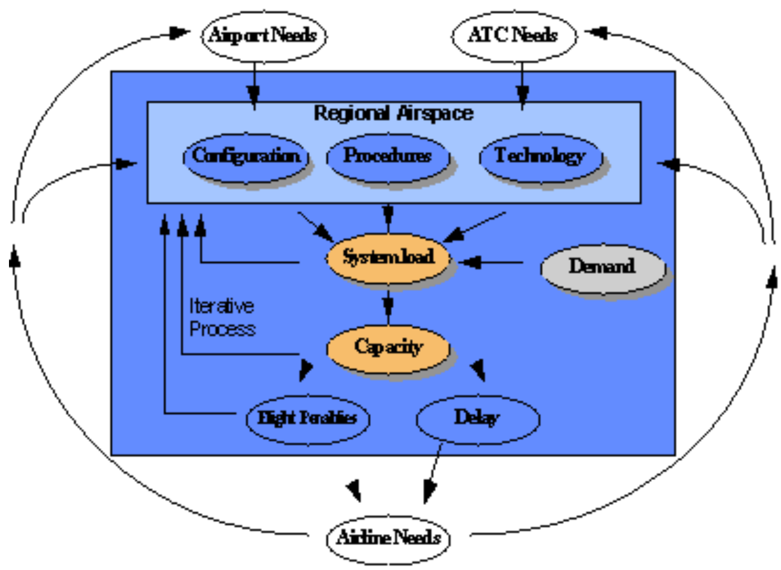


Figure 13: SIMMOD/RAMS:
Airport /airspace simulation

ATC simulations are based on four types of input data:

- Configuration (sector units and manning)
- Procedures (for control, transfer of information and separation)
- Technology influences (e.g. automation of controller tasks or changes to task duration)
- Traffic pattern (including aircraft type, routes and flight level restrictions)

RAMS identifies controller workloads and estimates sector capacities based on the Heavy Workload Threshold (HWT) defined at 70% (the factor HWT = 70% has been defined based on EUROCONTROLs 17 years of ATC simulation experience).

RAMS allows several methods of iteration (figure 13):

- configuration (sectorisation) can be modified to reduce the average number of sector penetrations per flight and to achieve a good balance of workload amongst the simulated sectors given system load (FAP uses this option to define the relationship between sector splitting and capacity gain; when do we reach the point where sector splitting becomes inefficient?)
- procedures can be modified to reduce workloads and increase capacities (FAP uses this option to identify workload intensive procedures and to investigate future concepts)

- technology can be modified to reduce workloads and increase capacities (FAP uses this option to investigate the impact of new technology)
- demand and traffic pattern can be modified (FAP uses this option to investigate the impact of traffic growth and complexity on controller workload)

FAP simulates new ATM actions (e.g. those identified by EATCHIP) applied to the representative airspace of the four airspace classes to identify potentials for capacity improvement and catalogues them in a 2D matrix by ATM action and airspace type.

Building up future ATM scenarios

We know now where the problems are, their severity and characteristics. We also have a set of possible actions/options plus their potentials to solve the capacity problem. The information can be used in a top−down and bottom−up approach:

- **top−down approach**
  1. Specification of the future ATM strategy (decrease delays, provide service at optimum costs, no degradation to safety etc.)
  2. Identify the regional capacity targets
  3. Search for the best options to meet the capacity targets under consideration of the regional and functional differences in the ATM systems.

- **bottom−up approach**
  1. Investigate an ATM action and its potential to increase capacities under the various conditions of the ATM systems throughout Europe.
  2. Determine the impact of the capacity increase on the performance of the ATM system at the ECAC level.
  3. Evaluate the potential cost/benefit for the development and implementation of such an ATM action for Europe.

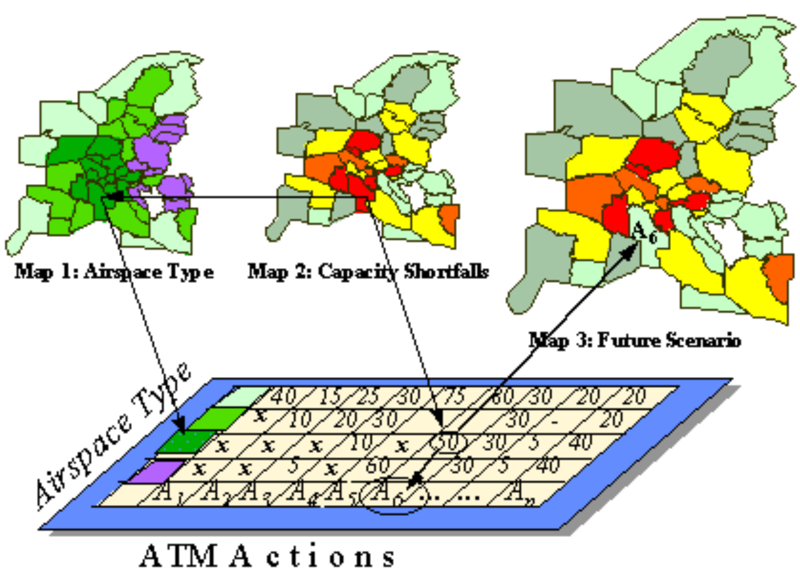


Figure 14: Top down approach to build up a future ATM scenario

The way the future scenario is built up depends on the approach. Figure 14 shows an example (with fictitious data) using a top−down approach.

We assume that ATFM simulations have revealed that some ACCs need capacity improvement of x% (given through Map 2). ATM actions to increase the capacities are selected based on the airspace type (Map 1), the feasibility (compatibility) and the potential to improve the capacity in that region (Matrix: Airspace Type − ATM Actions). Map 3 is the chess board on which the new scenario is built up (using the reference as a starting point). In a sort of creative dialog between the existing information and expert knowledge, successive ATM actions are allocated until all capacity shortfalls are eliminated.

In this step the implementation of options are evaluated based on

- their ability to solve the regional capacity shortfall
- their feasibility (are all necessary base components available)
- their compatibility (interference with other ATM units)

Estimation of the Benefits

Costs and benefits are measured against a "Reference Scenario" (e.g. a "do nothing").
The scenarios comprise all necessary traffic, regulation and configuration data of 2−3 selected days.

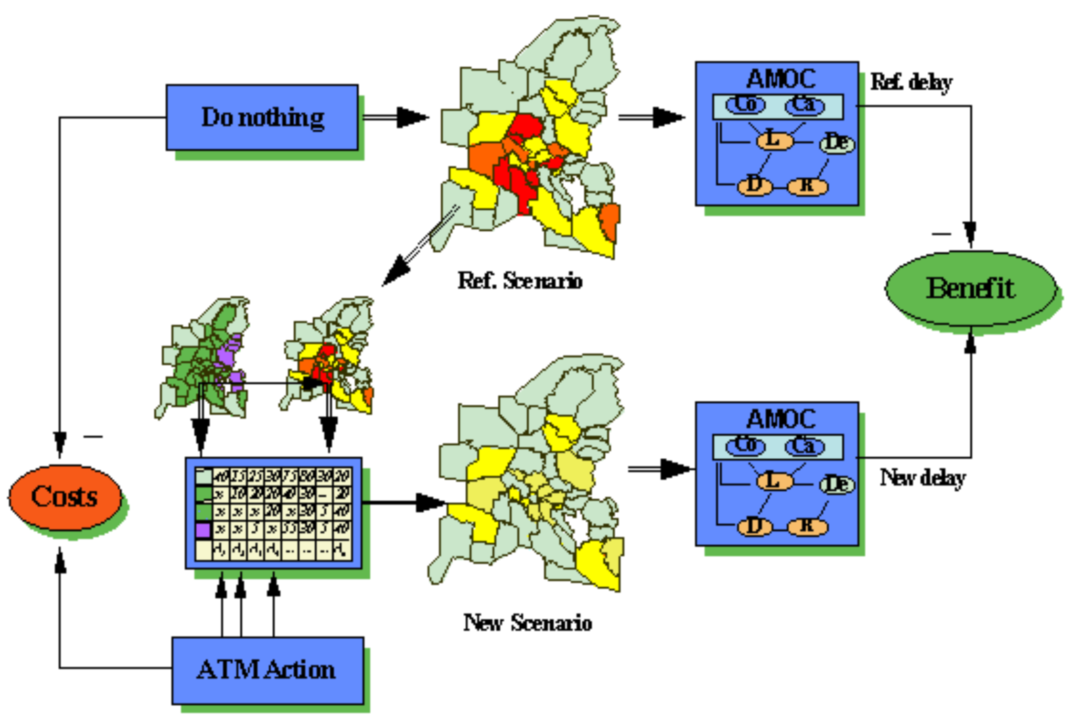


Figure 15: Cost/Benefit Analysis

The new scenario is built up on the reference scenario and adds new elements subject to the cost/benefit analysis.

Candidates for cost/benefit analysis can be individual EATCHIP ATM actions or completely new scenarios. Candidates can be globally or regionally applied. However, regionally applied candidates can have global impacts (ECAC wide).

In this step evaluation of the candidates is performed based on

- their cost effectiveness (implementation costs versus potential delay reduction)

Conclusion

This paper is offered to foster understanding of main ATM and airport issues in the aviation community based on currently available research results. These results need to be further refined, discussed, amended where necessary and validated. Therefore, conclusions cannot be considered as final.

Nevertheless, it has been proven possible to develop a promising tool in a limited timespan, and at a limited cost. This was achieved through the merging of operational ATFM, ATC and ASM knowledge together with engineering and R&D expertise and by using a combination of existing models in a three−layers structure of the ECAC ATM system:

- FAP is the first combined ATFM and ATC fast time simulation study covering the entire ECAC area combining:
  − ATFM restrictions en−route and airport and
  − ATC modeling

- FAP projects the Performance Indicators into the future as an input to the Performance Review System with the objective to achieve a common understanding between all partners, such as ATC providers, airports, airline and charter companies, general aviation, governments and national administrations. Such a common understanding is a prerequisite for proper identification of present and future ATM problems and for the development of solutions through which these could be tackled in the future.

- FAP provides answers to questions like:
  − Where are the bottlenecks (geographically, air/ground, upper/lower airspace),
  currently and in the future?
  − What are the capacity shortfalls, currently and in the future?
  − What is cost optimum for the airspace user(s): extra capacity or delay?
  − How can capacity be improved?
  (problem & action => potential benefit)

- FAP results can be used to build up a symptom−diagnostic catalogue, assisting decision makers in the identification of the most pressing problems requiring urgent decisions, and the most promising actions for capacity improvements best suited to the particular problem in the simulated area.

- FAP provides major elements for cost/benefit assessments to assist optimum allocation of investments in the European ATM systems.

Abbreviations

ACC Area Control Centre
AMOC ATFM Modeling Capability
ATC Air Traffic Control
ATFM Air Traffic Flow Management
ATM Air Traffic Management
CASA Computer Assisted Slot Allocation
CFMU Central Flow Management Unit
CIM Capacity Indicator Model
CIP Convergence and Implementation Programme
CRCO Central Route Charges Office
DPS Data Processing System
EATCHIP European Air Traffic Control Harmonization and Implementation Programme
ECAC European Civil Aviation Community
FDPS Flight Data Processing System
FUA Flexible Use of Airspace
IATA International Air Transport Association
PRC Performance Review Commission
RAMS Reorganized ATC Mathematical Simulator
RVSM Reduced Vertical Separation Minima
TACOT TACT Automated Command Tool