A DATA CLUSTERING APPROACH TO IDENTIFY LOGICAL FUNCTIONAL ATFCM AREAS

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Abstract

The paper presents the methodology designating to identify the network effect between a global set of capacity constraints made of sector and airport capacities. The goal is to solve this problem as locally as possible, this being possible by reducing the difficulty of global network impact assessment problem through the definition of Logical ATFCM Functional Areas (LFAAs).

First, a new approach for the evaluation of the current network effect handled by the CFMU (EUROCONTROL Central Flow and Management Unit) slot allocation process is proposed. The assessment methodology including the definition of network effect indicators and statistical results are presented so as to provide a global insight of the network effect intensity and distribution.

While this approach addresses network effect assessment in the post-operations phase, the second part of the paper introduces a methodology and key concepts aiming at anticipating the network effect through the definition of LFAAs.

Thus, the present study aims to provide the initial methods, key concepts and tools to the definition of functional ATFCM areas.

Introduction

As stated in the SESAR (Single European Sky ATM Research) programme [1], the determination of solutions that cope with capacity/demand imbalances should be designed through "a pan-European planning and coordination between all stakeholders, both at the strategic and tactical levels".

To fulfill this aim, the future ATM processes should provide a predictable and stable system that "simplifies and increases the transparency of collaborative decision making processes".

This goal would be delivered through a collaborative layered planning [2] at local level supported by a Network Management Function which determines, balances, refines, and then optimises capacity and demand on the basis of common situational awareness of the ATM picture and network effects resulting from the stakeholders' decisions.

This fundamental principle implies for the Network Management Function to have the means for a clear collaborative and information sharing process, including the identification of the involved actors, the appropriate solutions, and the assessment of their possible interdependence enabling to anticipate the network effect resulting from these solutions during the strategic phase.

This predictive function is the basis around which Collaborative Decision processes will be organised. Hence, the aim of this paper is to provide key concepts and approaches that contribute to the automation of the predictive function in order to reduce complexity and increase efficiency of the Network Management process.

Starting from a post analysis study, the paper presents a methodology which assesses the network effect generated by the application of the Central Flow Management Unit (CFMU) ATFCM measures. This methodology, developed by the EUROCONTROL Experimental Centre (EEC), provides the key elements that enable to understand network effect mechanisms.

Subsequently, the definition of LFAAs will be based on the evaluation of network effect indicators and data clustering techniques. Some of the initial LFAAs have been designed and are presented hereafter to better illustrate the followed approach. They should not be considered as final solutions. Further work, including the calibration of the clustering model and operational evaluation is in progress.

Network Effect Concept

The methodology developed at the EEC has been designated to evaluate the impact of simulated and real ATFCM measures managed by the CFMU operations. It is briefly presented below.

Definition

Network effect is the expression designing a throughput variation associated to a traffic volume and resulting of ATFCM measures that is applied to another traffic volume.

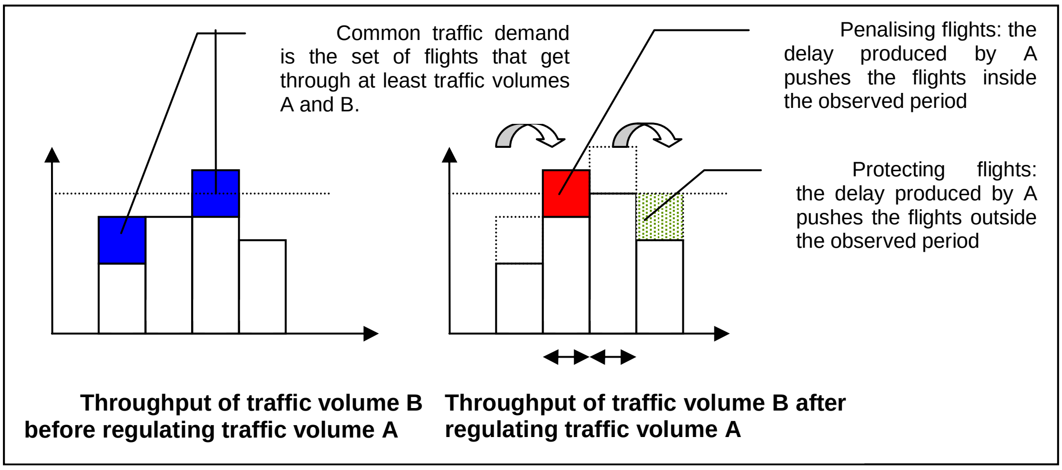


Figure 1. Planned throughput variation generated by network effect

Traffic volume (TV) is associated to an airspace element (sector, a group of sectors, beacon, a set of beacons, airport, a set of airports) that is constrained by a limited capacity and may require being protected by applying an ATFCM measure such as ground delay, re-routing or level capping, during a while.

The present study will focus on ground delay measures applied by the CFMU to Traffic Volumes, in order to eliminate the expected capacity/demand imbalances over the European Civil Aviation Conference (ECAC) area.

Indicators

When applying a ground delay measure to a TV, the impacted flights may have a positive or negative effect upon the other Traffic Volumes.

When delayed flights increase the throughput of a more or less distant traffic volume, they are termed "penalising flights" or **penalisations.** Conversely**,** they are called "protecting flights" or **protections** when they decrease traffic volume throughput.

The number of protections and penalisations produced by a TV is strongly correlated to the amount of common traffic demand.

Figure 1 shows how a regulated TV can produce simultaneously protecting and penalising effects upon another traffic volume.

In order to assess the final effect of a regulated TV upon another TV, one has to subtract the number of protections and penalisations. The resulting value is called the **interaction**: A positive value of interaction means a decrease of throughput, while a negative value corresponds to a throughput increase.

Network effect assessment process

The method presented hereafter aims at evaluating the network effect following the application of a set of flow management measures that protect TVs.

Indeed, the CFMU offloads the expected saturated sectors and airports on the basis of a set of ATFCM measures, and by using a centralised departure slot allocation system called CASA (Computer Aided Slot Allocation).

The CASA system assigns a departure slot to a flight that enters the restricted areas according to its estimated entry times within these areas. The first planned first served principle is applied.

All the flights delayed by a regulation will generate a network effect upon the other regulated areas but also upon non regulated areas, producing a risk of saturation.

As explained previously, the network effect for a given TV reflects the part of throughput variation which is produced by external regulations.

Evaluation of the network effect in the ECAC area requires extracting and processing real CFMU data in order to build an appropriate sample of significant traffic volume throughput variations.

The complete process of network effect evaluation is composed of four main steps:

- **Step 1: Selection of traffic scenarios**

The first step consists in selecting traffic sample from historical data provided by the CFMU.

- **Step 2: Evaluation and selection of throughput variation occurrences**

Traffic volume throughput is evaluated for each sup-period (20-minute slices), before and after the flow measures activation. Then, the discrete evolution of traffic volumes throughput variation is observed. Each variation is defined by its amplitude (positive or negative) and duration.

Then, the throughput variation events sample is built on the basis of relevant observations, defined through two criteria: the amplitude of fluctuation must be greater than a predefined throughput variation threshold value; the traffic volume is saturated most of the event duration.

- **Step 3: Evaluation of network effect indicators matrix**

The process of counting the number of protecting and penalising flights previously explained will be applied. Hence, for each selected fluctuation event the process identifies the protections, penalisations and interactions generated by each linked traffic volume.

At the end of the process, each indicator is presented in a matrix that provides, for each pair of traffic volumes, the observed number of protections, penalisations, interaction, and absolute network effect.

- **Step 4: Identification of subnets structure using data mining techniques**

Previous steps focused on the evaluation of network effect indicators considering each pair of traffic volumes independently. This step aims at identifying structured airspace entities linked by network effect dependencies providing an overall vision of the degree of dependence among the traffic volumes that is generated by the airspace structure, traffic assignment, and the centralised slot allocation mechanism.

The most classical approach to the identification of groups of objects sharing specified relationships is provided by clustering techniques in data mining.

Three clustering algorithms have been retained from the literature review: single linkage, average linkage and complete linkage algorithms (cf. [3]). They offer adequate strategies for the composition of structured airspace based on network effect relationships.

Network Effect Assessment Results

Throughput variation events have been sampled for 28 days of a summer 2005 Aeronautical Information, Regulation and Control (AIRAC) cycle for traffic volumes of the ECAC area subject to flow management restrictions. The following results and conclusions can be drawn.

Analysis by Pairs of Traffic Volumes

This analysis provides an insight of the interactions occurring between two traffic volumes of the sampled events in terms of intensity and occurrence.

As previously explained the **interaction** value is the final effect of overlapped protecting and penalising flights that is generated by a given regulated traffic volume upon another traffic volume. Two categories of impacted traffic volumes are distinguished in Figure 2: regulated traffic volumes and non regulated traffic volumes.

It can be noticed from figure 2 that the amplitude of interactions between two traffic volumes is settled within the interval [-5, 5], and a great proportion of both regulated and non regulated periods (77% and 65% respectively) are impacted by very slight interactions, fluctuating between -1 and 1. The small proportion of zero interaction value is related to the elimination of the small fluctuations from the selected sample.

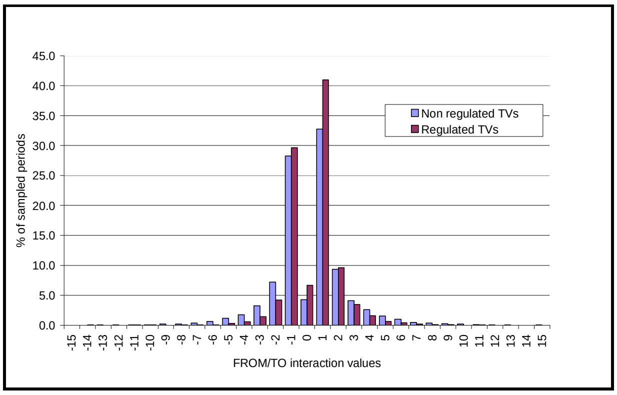


Figure 2. Distribution of Interaction values

It can be concluded that a regulated traffic volume does no**t significantly** impact another traffic volume **individually**. However, we can assume that throughput variations generated by the network effect is the result of cumulated effect of several regulated traffic volumes. The next step of the analysis attempts at assessing this assumption.

Analysis of regulated TVs

In order to know whether regulated periods are impacted by a significant network effect in comparison with the total fluctuation of this regulated periods, Figure 3 presents, for each variation value, the sum of corresponding sampled variations by splitting the part generated by the network (the impact of outside regulations) and the self-impact of the regulation.

The analysis shows the importance of network effect contribution that represents **on average 30%** of the throughput variation amplitude (see. the purple histogram)

This result confirms the initial result that significant **network effect is the result of the accumulation of small individual TV effects.**

Thus, the centralised slot allocation mechanism behaves in a way that small but cumulated contributions of a large number of regulated traffic volumes upon an individual traffic volume could lead to important throughput variations.

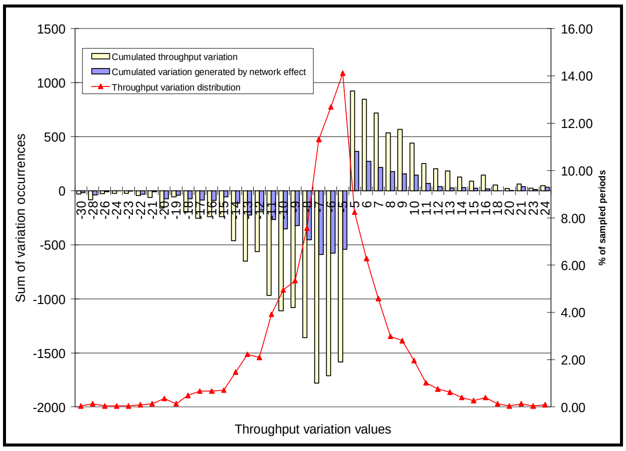


Figure 3. Network effect contributions in throughput variation for regulated periods

TO TV interactions case study

In the following, one specific traffic volume is selected (EDMMSR45) in order to analyse in details its connection to the network.

The table on the right of Figure 4 displays the **maximum values** over the 28 sampled days displaying all the computed network effect indicators.

On the map, the sectors associated to each traffic volume are coloured in red or green depending on the sign of the interaction value: green if it is positive and red if negative. The colour of the traffic volume brightens up as the interaction value increases (in absolute value).

It can be shown the great number of traffic volumes impacting the traffic volume EDMMSR45.

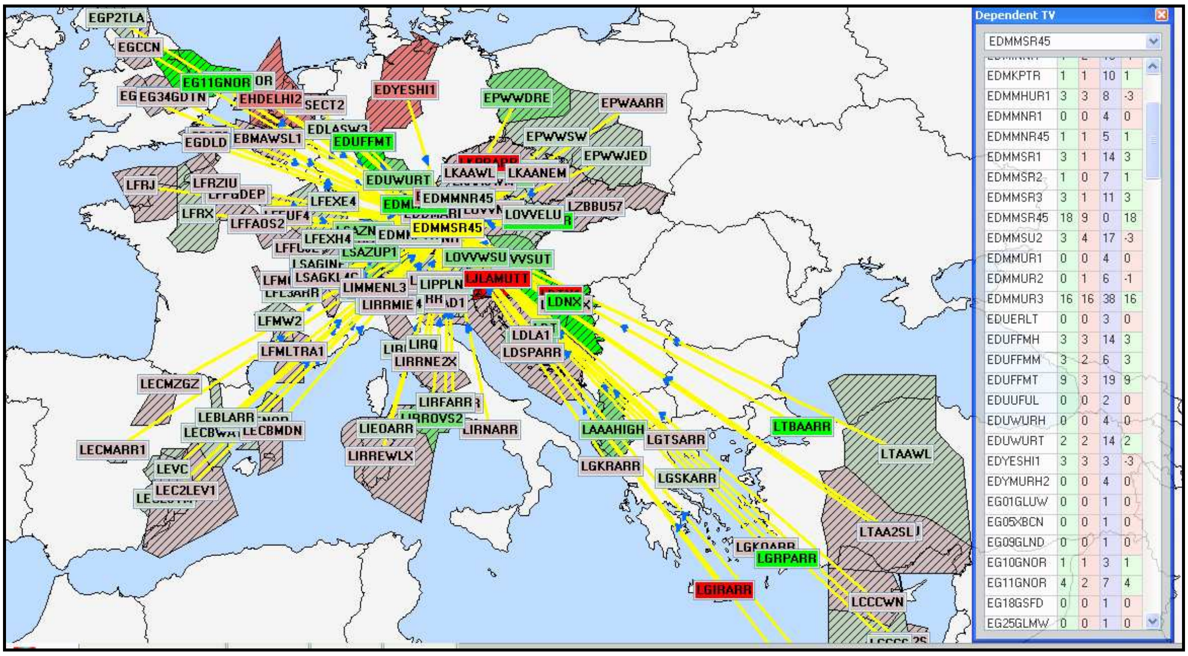


Figure 4. Maximum of interactions received by EDMMSR45

The impact of flow management measures upon a TV such as EDMMSR45 is spread over a large number of possible TVs combinations.

Figure 4 shows that interaction intensity values are mostly weak (cf. the table values). A small number of traffic volumes are impacting the analysed traffic volumes with a significant value (cf. TVs in bright green and bright red) while most of them are neighbours.

The network effect characteristics drawn above are the consequence of a complex network environment resulting from:

- A highly interconnected routes network
- A traffic assignment
- Sectorisation
- TV definition
- A global application of ATFCM measures

This has the advantage of diluting the network effect, but the drawback to making difficult global assessment. Moreover, the stability of the impact cannot be learnt thus predicted.

Assessing Network Effect Structures

The network effect assessment methodology proposes in step 4 the identification of structures composed of strongly connected traffic volumes.

This important step will enable to draw the geographical boundaries to network effect extension and assess the stability of these structures through a recurrence analysis.

These analyses have not been achieved in the context of this paper; however an example of structure identification is presented below so as to illustrate the potential contribution of this step in the framework of network effect management.

Traffic volume structures identification consists in merging regulated and non regulated traffic volumes according to their mutual degree of interdependence.

The first step of the identification starts from a matrix of common demand values upon which is applied a clustering algorithm.

In order to merge a maximum of interacting traffic volumes, the merging process is performed through the single linkage principle that produces groups of traffic volumes where each element of a group is connected to at least one element with a common demand value stronger than a given common demand threshold value.

As a result, groups' composition will be used to arrange the matrix of network effect indicators accordingly. If important correlations between the shared demand and network effect indicators can be established (as showed in the example below) that would advocate for a relevant use of the shared demand indicator in the identification of ATFCM structures.

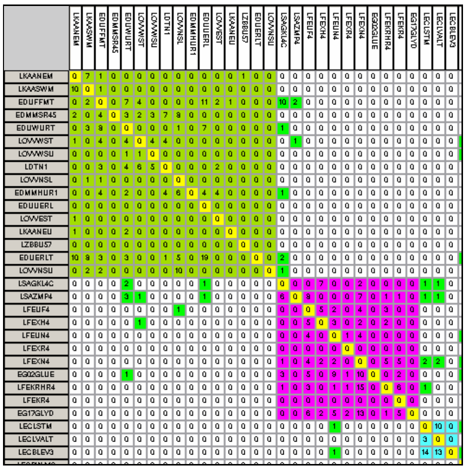


Figure 5. Structured Network Effect Matrix

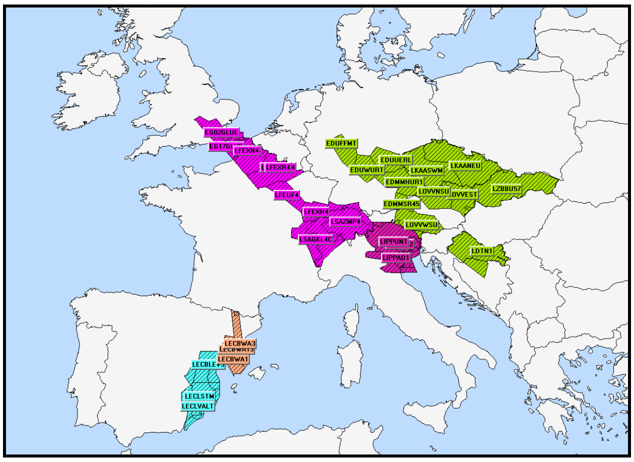


Figure 6. Connected Traffic Volumes Structures

From Network Effect Analysis to LFAAs concept

It is likely to consider previous network structures identification approach as a means for the definition of homogeneous functional areas for which ATFCM measures could be applied ensuring that network effect is localised inside the defined area and is almost inexistent outside.

Therefore, this section presents a methodology and key concepts that enable to anticipate the identification of groups of quasi independent ATFCM bodies termed by Logical ATFCM Functional Areas (LFAAs). The identification of such areas aims to improve the coordination within the ATFCM decision processes and consequently network efficiency.

Furthermore, the proposed method has to be calibrated and validated with the help of operational network manager experts in view of a potential implementation in the framework of future ATM systems modelling.

LFAAs objectives

This section aims at answering the question of what are the potential applications of Logical Functional ATFCM Areas concept in the operational context.

LFAAs concept is inspired from existing operational practices developed by the CFMU through the NOP (Network Operations Plan). The identification of two areas referred as the South-West and North-East axis in which a set of Collaborative Decision Making (CDM) procedures have been set up is an illustration of what would be the LFAAs and their use [4].

LFAAs identification method can be generalised to the ECAC area as a basic concept for the validation activities and more precisely for those related to NOP building and collaborative decision making processes.

Therefore, the LFAA concept could contribute to improve the efficiency of ATFCM CDM processes by providing guidelines for reducing the number of relevant actors involved in the implementation of pre-defined scenarios.

Furthermore, for a given pre-defined scenario or any ATFCM measure, the definition of LFAAs boundaries together with the evaluation of network effect indicators would continuously enrich NOP processes with structured and relevant input data that help to improve the network performance and efficiency.

Finally, LFAAs definition could also simplify the CDM process in tactical phase by quickly and fully anticipating and evaluating the interactions within the network and consequently by applying the appropriate ATFCM measures that ensure network efficiency.

LFAAs definition

Regarding the ATFCM system objectives, the concept of LFAAs would be inevitably related to the identification of the traffic demand structure, which is provided by the main flows directions/axis. Main flows represent the strongest links between sectors, while minimising the network effect between each other. In addition, it is also to consider the possible re-routings of these flows.

Hence, LFAAs are expected to be formed by the main flexible and relatively independent flows linked by potential re-routings.

LFAAs design process

The designing process addressed in this paper concerns the identification of LFAAs at the strategic ATFCM phase.

This section presents the experimental framework and the design process for which each step is illustrated by the corresponding network decomposition result.

Designing principles

Designing LFAAs will follow an iterative process based essentially on a statistical approach but also on the expertise of network managers that help to refine and validate the first statistical modelling iterations.

It is important to recall that the designing approach presented in this paper, concerns the strategic phase of ATFCM system. This will require the definition of stable entities based on the identification of existing demand patterns.

Experimental framework

The first experiments for the identification of LFAAs are performed under the conditions described hereafter.

Traffic demand scenarios

In order to ensure the consistency and the stability of the LFAAs structures, the design method will use a multiple days' traffic demand scenario.

The multiple days' scenario ensures that flows will use a great number of possible routes and establish statistically the possible links between the re-routable flows.

A set of 8 week-end days is selected over the AIRAC cycle 284 (July-August 2006).

Environment

To perform a refined definition of the LFAAs boundaries the evaluation of the demand dependencies will be achieved over elementary sectors, which are the smallest control unit used by the Area Control Centres (ACCs).

Tools

The Visualisation and Analysis of the Network Effect Tool (VANET) developed by EEC is used to evaluate the connectivity between the sectors, to identify the main flows and assess the interdependence between the identified flows on the basis of data clustering processes.

Experiments Parameters

In table 1 are given the parameters for the first two iterations of the design process.

The use of those parameters will be explained when detailing the process iterations.

Table 1. Clustering Parameters

	Merged elements	**Linking criteria**	**Thresh value**
Iteration 1	Elementary sectors	Common demand	320
Iteration 2	Main Flows	Average common demand	120

Iteration 1: Grouping the elementary sectors

The first step aims to identify the basic flows corresponding to the strongly connected sectors.

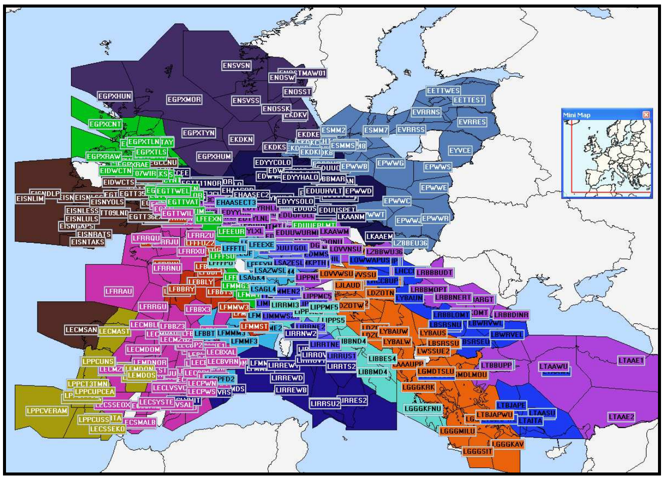
Hence, the identification of a basic flow consists in merging the highly connected sectors within a same group (main flow).

In order to ensure the stability of the clustering process, the average linkage principle will be used: for a given common traffic demand threshold average linkage method allows a sector to join a group (main flow) if the average common demand between this sector and all members of the group is greater than the given threshold.

It is worth to notice the importance of selecting an appropriate common demand threshold value, since it determines the characteristics of the decomposition and the connectivity of the formed flows.

Several experiments have been achieved so as to determine the best threshold value regarding the number of sectors merged and the internal connectivity of the formed flow. The connectivity indicator is given by the average common demand of the sectors composing the flow and is displayed in the main diagonal of the interdependence matrix.

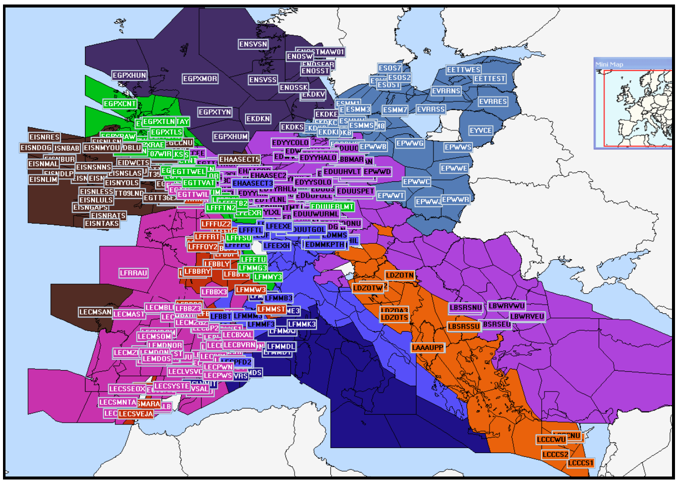
The selected threshold for identifying the basic flows at the first iteration is established at 320 flights for the eight days scenario (or 40 flights per day on average), as presented in Table 1.



Sectors Matrix | % Com Demand Min | Av Com Demand | Nb Connection

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	418	39	90	149	70	141	164	82	65	16	25	24	12	23	49	74	15	21
1	39	430	49	29	105	9	5	117	11	145	103	73	122	18	1	34	26	23
2	90	49	434	39	32	95	41	125	32	16	10	124	23	7	7	153	42	3
3	149	29	39	524	70	66	82	44	174	12	20	11	9	83	51	20	4	45
4	70	105	32	70	498	33	11	111	21	29	67	44	37	44	5	52	71	67
5	141	9	95	66	33	432	152	40	47	1	5	36	3	8	23	113	14	0
6	164	5	41	82	11	152	454	17	68	0	2	15	1	6	98	17	12	0
7	82	117	125	44	111	40	17	443	18	26	21	103	102	12	2	97	154	7
8	65	11	32	174	21	47	68	18	429	2	2	6	2	63	53	9	2	2
9	16	145	16	12	29	1	0	26	2	492	89	16	21	3	0	2	9	26
10	25	103	10	20	67	5	2	21	2	89	395	9	22	5	1	12	10	166
11	24	73	124	11	44	36	15	103	6	16	9	501	47	2	3	106	42	1
12	12	122	23	9	37	3	1	102	2	21	22	47	425	3	0	16	83	2
13	23	18	7	83	44	8	6	12	63	3	5	2	3	447	3	2	2	11
14	49	1	7	51	5	23	98	2	53	0	1	3	0	3	438	5	1	0
15	74	34	153	20	52	113	17	97	9	2	12	106	16	2	5	517	28	3
16	15	26	42	4	71	14	12	154	2	9	10	42	83	2	1	28	483	4

Figure 7. Iteration 1 - Basic Flows Identification and Resulting Interdependence Matrix



Sectors Matrix | % Com Demand Min | Av Com Demand | Nb Connection

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	244	22	56	109	51	17	81	6	18	10	57	31	84	71	24	70	22	4
1	22	309	53	6	84	68	8	86	44	29	0	13	5	4	4	11	1	77
2	56	53	245	69	57	10	21	33	104	77	5	8	22	14	3	15	24	10
3	109	6	69	366	27	3	36	2	31	10	22	7	38	50	13	9	75	1
4	51	84	57	27	432	60	18	29	50	53	4	41	8	4	15	9	1	28
5	17	68	10	3	60	271	1	11	9	6	0	6	2	1	0	1	0	103
6	81	8	21	36	18	1	323	1	6	2	42	50	42	59	85	43	9	0
7	6	86	33	2	29	11	1	265	32	58	0	2	2	0	0	3	0	60
8	18	44	104	31	50	9	6	32	329	37	3	2	6	5	0	5	8	16
9	10	29	77	10	53	6	2	58	37	271	1	1	4	2	0	1	3	15
10	57	0	5	22	4	0	42	0	3	1	362	3	15	27	5	6	4	0
11	31	13	8	7	41	6	50	2	2	1	3	412	3	3	82	17	0	1
12	84	5	22	38	8	2	42	2	6	4	15	3	283	64	10	23	30	0
13	71	4	14	50	4	1	59	0	5	2	27	3	64	295	11	8	26	0
14	24	4	3	13	15	0	85	0	0	0	5	82	10	11	344	7	2	0
15	70	11	15	9	9	1	43	3	5	1	6	17	23	8	7	316	2	0
16	22	1	24	75	1	0	9	0	8	3	4	0	30	26	2	2	234	0

Figure 8. Iteration 2 - Main Flows Identification and Resulting Interdependence Matrix

Therefore, the main flows resulting from the average linkage clustering process would be composed of sectors having shared demand higher than 320 flights on average.

The mains flows and their remaining interconnectivity values (i.e. average common demand) are displayed in the map and the matrix of Figure 7 respectively.

The large values of the internal connectivity displayed on the main diagonal of the matrix can be compared to the inter flows connectivity values.

Table 2 provides some additional results such as the number of sectors composing the biggest flow and the number of flows composed of more than 10 elements.

In addition, iteration 1 seems to succeed in the identification of the basic flows that compose the North-East (NE) axis (Cf. Flows number: 0, 3, and 6 in Figure 7) and the South-West (SW) axis (Cf. Flows: 1, 9, and 10). These axes are two regions currently managed through collaborative decision processes to resolve the airspace bottlenecks occurring in these areas. The identification of such regions based on structure of the demand will be the input for the assessment of LFAAs identification approach. More details will be provided further.

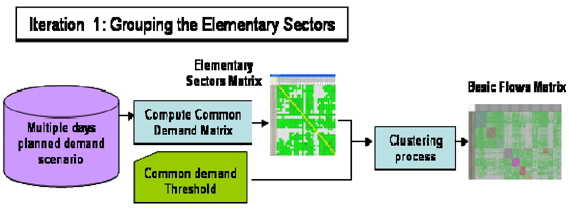


Figure 9. Basic Flows Identification Process

Iteration 2: Grouping the basic flows

Having the set of basic flows and their interdependence matrix (Cf. Figure 7) the second iteration will merge the highly connected basic flows and form the main flows.

The process uses the average linkage principle to group the basic flows with a threshold of average common demand of 120 flights.

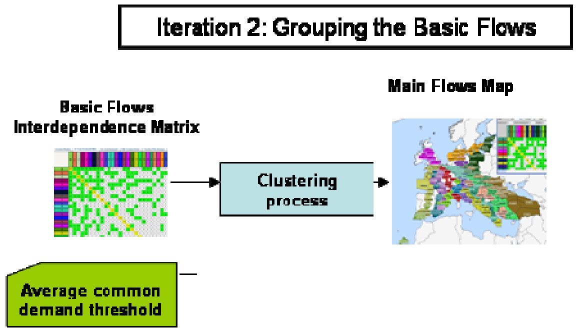


Figure 10. Main Flows Identification Process

The resulting main flows are displayed in Figure 8. It could be noticed that the interdependent flows of "South-West" and "North-East" axis, previously identified, have been merged at the second iteration, since their interdependence values, at the first iteration were higher than the fixed average demand threshold.

Table 2. Additional clustering results

	Nb. sectors in the biggest flow	**Number of flows with more than 10 sectors**
Iteration 1	88	19
Iteration 2	183	16

Iteration 3: Grouping the main flows

Starting from elementary sectors and arriving to main flows, the merging process will carry on recursively until the LFAAs are formed. At the current stage, most of the possible re-routing should have been included within their respective main flow. However, some possible re-routings occurring between two main flows and establishing a functional relationship between these flows will complete the LFAAs design process by grouping the "re-routable" main flows.

Two grouping approaches can be used depending on the availability of expertises concerning each main flow. The first approach is operational: since the number of flows is reduced, the flows could be merged on the basis of network manager experience and knowledge.

If the possible re-routings between the main flows cannot be assessed by operational expertise, a statistical approach will be used. This approach is displayed on Figure 11: starting from past traffic demand, the process identifies all the possible re-routings by origin/destination pair. Then, all the scenarios will be used to build a virtual traffic demand file and its associated common demand matrix. When this matrix is ordered according the main flows matrix, the possible routes between the main flows will be identified.

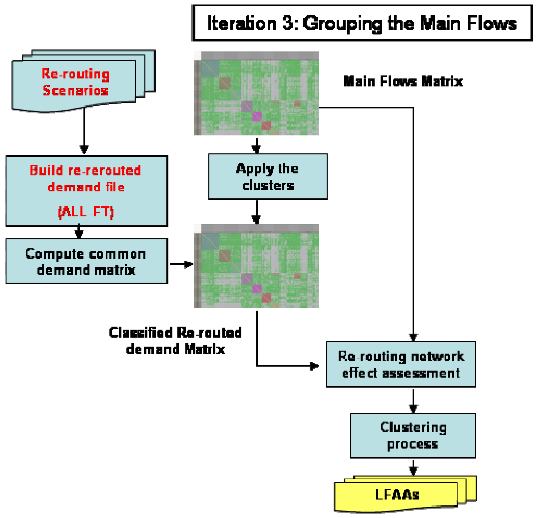


Figure 11. Composing the LFAA's

Iteration 4: Calibration of the model

When LFAAs design process is completed, the aim of the calibration phase is to compare the ATFCM regions identified operationally (SW and NE regions) with those calculated by the design process (Cf. Figure 13) and adjust the common demand threshold value according an iterative process, described below, until the appropriate thresholds are identified.

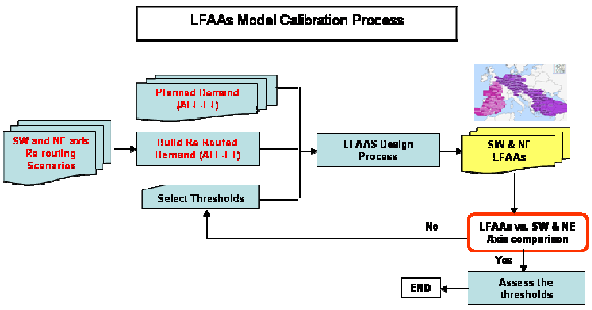


Figure 14. Calibrating the LFAAs model

LFAAs operational assessment

The objective of this phase is to validate the operational feasibility of the LFAAs design approach. While, the calibration phase compares calculated LFAAs with existing ATFCM regions, the operation assessment will confront new calculated LFAAs to the operational point of view (Cf. Figure 14).

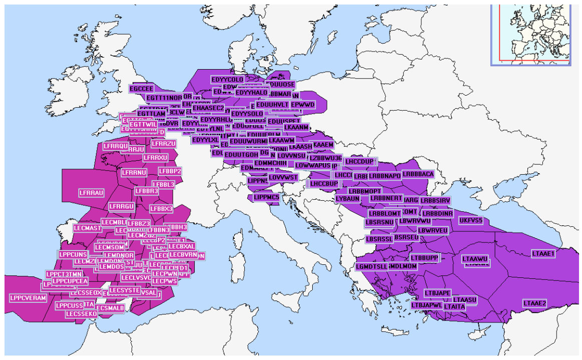


Figure 13. SW and NE axis issued from the LFAAs design process (Iteration 2)

When the designed LFAAs are not in adequacy regarding operational considerations, the design process must be refined in order to take into account the relevant operational constraints that have been identified during this phase.

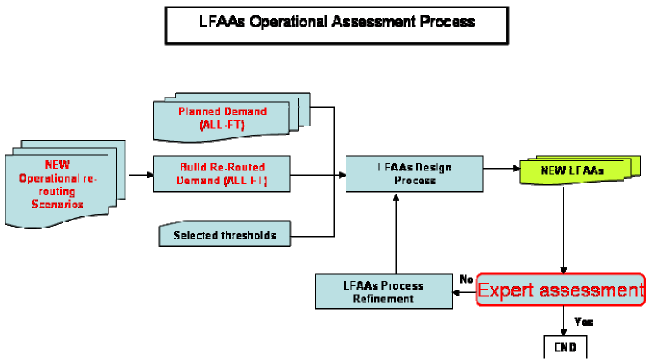


Figure 15. LFAAs Operational Assessment

LFAAs sectors typology

Finally, after the identification of new LFAAs and their operational validation, each resulting LFAAs is then composed of re-routable main flows which in turn are formed by strongly dependent elementary sectors ensuring a high internal functional connectivity.

However, even if the merging process is based on the maximisation of internal dependencies and the existence of potential re-routings, it will remain some inter LFAAs connections corresponding to the common demand of sectors that belong to several LFAAs at the same time.

In order to assess the interconnectivity between LFAAs, a typology of the sectors composing the LFAAs is proposed.

Two categories of sectors are distinguished: weakly connected sectors named “flow oriented sector” and strongly interconnected sectors named “connecting sectors”.

Connecting sectors will be assigned a sector/LFAA connectivity indicator value which assesses the degree of membership of the sector to each LFAA.

The result of the overall LFAAs design process is illustrated within the model of Figure 16**.**

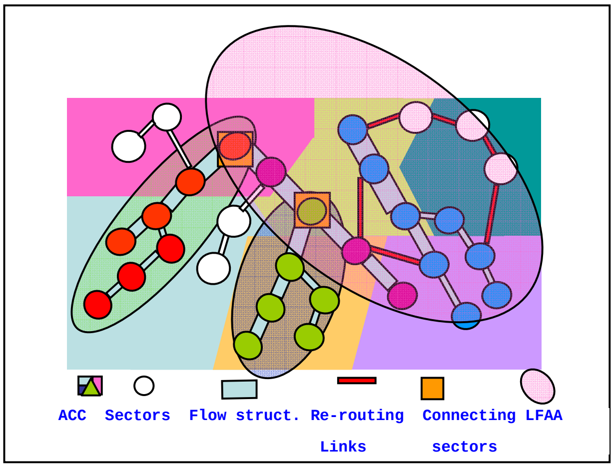


Figure 16. A model for LFAAs Structure

Conclusion

The paper proposes a network effect assessment methodology that enables the analysis of network effect through a global perspective. The approach is applied for the assessment of Post Operations network effect. However it can be exploited as basis concepts for the prediction of network effect of any type of ATFCM measures (ground delay, re-routing, level capping, etc.) and at each planning stage.

As regard LFAAs design, the proposed methodology is a first research step aiming at offering the basic elements for the identification of airspace regions that strongly fit the air traffic pattern.

This approach enables to anticipate the identification of groups of homogeneous ATFCM bodies and the identification of the inherent collaborative networks.

The designed LFAAs, at their first stages provide encouraging results.

Besides LFAAs design, the approach offers a structured information related to network effect which would contribute to create more explicit and efficient Collaborative Decision processes.

Biography

Leïla Zerrouki is graduated Master in industrial engineering of the INPG (French National Polytechnic Institute of Grenoble) and has a PhD of the university of Paris VI in 1999. She has gained 8 years’ experience in Air Traffic Flow Management working on a variety of topics at EUROCONTROL Experiment Centre. Her current interests include the development and assessment of new concepts, metrics and prototyping computer assistance tools related to network analysis for the European ATFCM system.

Serge Manchon is a graduated engineer of the ENAC (French Civil Aviation School). He spent 9 years at CENA (national research center for the French CAA) as air traffic flow management project leader. In 1999, he worked for the SCTA (Air Traffic Control Services) as head of the “flow management and planning” subdivision. He joined the EUROCONTROL Experimental Center in July 2000 as expert in Air Traffic Flow & Capacity Management. He is currently working on the SESAR Single European Sky ATM Research concept.

Marc Dalichampt is graduated engineer of the ENAC (French Civil Aviation School). He joined EUROCONTROL Experimental Center in 1987 where he worked as expert, project leader, head or deputy head of Air Traffic Flow and Capacity Management. He is currently responsible of several activities within SESAR Single European Sky programme.

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