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Abstracts: *This paper presents an approach based on a multiple criteria decision making methodology (MCDM) to analyse the decisions of Air Traffic Controllers. This study will allow to model some tools able to assist the controllers in their tasks and particularly able to help them to assume the ceaseless increase of Air Traffic. Currently the platform AMANDA assists controllers on only one sector of control. This platform was very pleasant welcome, and we wish to extend these principles to adjacent sectors, and thus include tool to help the cooperation between adjacent controllers.*

This analysis is composed of three main points. First it is necessary to determine the decision making process of controllers. The second point consists of the application of the MCDM which guide all the study. And finally a repertory grid technique is applied in order to support the operational aspect of MCDM and to support the interviews.

We begin this paper by a presentation of Air traffic Control and the problematic, we present then AMANDA and its principles, and the objectives for the new version. In a third part we describe the approach developed and a real example of its application, the results and analyses that we can deduce of this first grid are also presented. These results must be, of course, confirmed and validated by the controllers.

Keywords: Decision Analysis, Multiple Criteria Decision Making (MCDM), Repertory Grid, Human-Machine Cooperation, Situation Awareness, Air Traffic Control.

1 Introduction

The DGAC (French acronym for General Direction of Civil Aviation) foresees that in the next 10 to 20 years the air traffic will double or even triple. This increase of traffic will be impossible to assume with the current control methods. Indeed in a mental point of view the number of aircraft and information to manage will be considerable and operators risk to be overloaded at certain times of the day, to the detriment of safety. It therefore becomes necessary to assist controllers in their work, offering them new tools and new ways of working that enable them to assume this increase.

The LAMIH works with the DGAC for many years in this optical. The laboratory has developed several platform with a common philosophy to keep the operator at the centre of the loop, and thus to develop cooperative systems. We now extend the principles developed in the last platform, and for this we have to understand how the planning controllers work.

For this we propose in this article a multiple criteria analysis will serve as support for the modelling of new space of cooperation between controllers of different sectors. We are going to apply the methodology of repertory grid to guide the collection of information, and extraction of knowledge, the operational part for the multiple criteria analysis.

We begin with a presentation of Air Traffic Control (ATC), with its problematic of traffic increase. The second part presents the AMANDA (Automated machine MAN Delegation of Action) project, in its current version as well as the objectives of the new version which is the subject of this article. A third part presents the approach that we put in place, which is divided into three parts, the decision-making process modelling, application of a methodology multiple criteria decision making (MCDM) to support our collection of information and then the repertory grid as operational aspects of the extraction of knowledge. Finally a final section presents our first decision model based on the expertise of a “decision engineer”.

2 Management of en-route air traffic

2.1 Organisation of Air Traffic Control

The ATC is organized in 3 stages: « Airport control », « Approach and terminal control » and « en-route control ». This latter level manages flights passing through in the airspace between departure airports to the approach control of the destination airport. Objective of en-route ATC is to guarantee the safety of aircraft. To do this the controllers must take care that aircraft remains above a minimum separation distance, while ensuring that they also respect the economic constraints of time and fuel consumption.

To simplify the management and the supervision of traffic, airspace is divided in geographical sector and in level of 1000 feet. A sector is permanently supervised by two controllers, composed of a Planning Controller (PC) and an Executive Controller (EC). PC coordinates the movement of aircraft between his sector and the adjacent sectors. This coordination consists in a negotiation of entrance levels and exit levels. The PC takes care too, to regulate the workload of EC. For his part, EC is in charge of sector supervision, namely the aircraft surveillance, the respect of flight plans, and maintenance of safety distances. If the EC detects a possibility of crossing under this safety distance, he/she must do all is possible to ensure that the separation distances are restored and the conflict avoided. Generally it is necessary to reroute one of the aircraft, and then to take back this aircraft in is original trajectory when the separation is guarantee. This action is called conflict resolution.

2.2 Motivation of the study

Some statistics can quickly demonstrate the problem of air traffic control. In 25 years (1977 to 2002) the traffic transiting in the French airspace has increase of 250% [1]. The Air traffic is today higher than 2.500.000 aircraft per year that gives on average 7.000 aircraft per day. In a sector like Bordeaux for instance, the controllers must manage 20 to 25 aircraft per hour, this is the reasonable limit of charge for the controllers. The DGAC foresee that in 10 to 20 years these statistics will double even triple. The controllers risk thus to have some difficulties to manage this increase with actual tools (radar view, strip, telephone, radio) and risk to be overloaded to certain moment of the day, and that to the detriment of the security. Reduce sectors is begun impossible, because the conflict resolution need a minimal geographical area.

Entirely automate the ATC is impossible too, outside psychological consequence that would lead to the passengers, the techniques to realise this automation, imply an entirely instrumentation of aircraft, that is not economically conceivable. Currently to avoid these surcharges, which could not maintain an optimal security level, different solutions are adopted, like the planning of flights and the regulation to the departure airports, or the coordination between sectors that allows reducing the complexity of air conflict even to avoid that these conflicts had really happen.

We approach the question in terms of assistance to the controllers. We propose to provide tools which help to improve the regulation of the workload of controllers. It is imperative that these tools come within perfectly the control tasks and the work of controllers (as a pair, as individually), to produce a beneficial effect.

3 Project AMANDA

It is in this perspective that the project AMANDA [2, 3], as well as others project developed in the laboratory since fifteen years [4, 5, 6], takes its place. These projects have always a same philosophy, which is to keep Human, operator, in the control loop. These projects do not therefore need to fully automate the management of ATC, which would result in loss of human competence of the operators, as well as a loss of situation awareness (SA) [7, 8], which would prevent operators to be able to react event of default by a system

3.1 AMANDA V2

AMANDA V2 assists controllers (PC and EC) of one sector, in giving some tools which be able to allow a delegation of task [3], but also some tools which can share rapidly a same representation of airspace, and conflicts, and thus to maintain a common SA.

3.1.1 Common Workspace

The Common Workspace [9, 10, 11] is an essential notion introduced with AMANDA. This space allows a sharing of information between all agents (human, like controllers and artificial like the tool of trajectory calculation). Each agent can introduce new information in this Common Workspace according to its competencies (know-how), and in accordance to its role (authority) in the process. All the agents can take this information into account in order to carry out their tasks, or to control and check those of the other agents.

The Common Workspace allows mainly to maintain common situation awareness between the two controllers, to share their representation of the problems (here in sense of air conflict or loss of separation) to supervise and/or to solve. The controllers have the responsibility to maintain up to date this space, in order to, on the one hand to preserve a coherent "picture" of the situation and airspace, and on the other hand to inform the platform, and mainly STAR, with conflicts that they detect.

3.1.2 STAR

AMANDA integrates a tool of trajectory calculation and to assist to the resolution of air conflict, calls STAR. STAR works in cooperation with controller. The controller detects a conflict (STAR does not make the task of conflict detection); he/she has the possibility to use STAR to help his/her to resolve the conflict. To do this the controller indicates the strategy (call directive) that he/she desires apply to resolve the conflict. A directive or strategy is like, for example, « AFR1542 PASS_BEHIND KLM1080 ». STAR takes into account this directive in order to propose a solution. To do this STAR calculates the whole of trajectories which response to the directive, without, of course, create new conflict. STAR proposes then ONE trajectory to the controller (after a choice in function of some criteria like number of deviation, consummation of kerosene…). The controller can examine the solution proposed by STAR. If the solution is satisfactory, the controller can delegate the application, that's mean the sending of instruction to aircraft. In this case STAR has in charge to communicate instructions (change of heading, FL…) directly to the aircraft, and discharge the controller of the application and communication with pilots.

3.2 Experimental results

The principles presented were tested experimentally with the help of qualified controllers regularly exercising their functions. For that three scenarios of traffic were designed to test three experimental situations differentiated by the level of assistance provided (see table 1). The scenarios simulated a realistic traffic (traffic configurations usual encountered on a real sector) but twice more loaded than into reality.

	Clusters, Problems	Strategy and solutions	Delegation
Scenario A	PC	No Help	
Scenario B	PC	PC	EC
Scenario C	PC	EC	EC

Table 1 Repartition of tools between the two controllers.

From a general point of view, the general principle of providing assistance allowing a regulation of workload has been recognized relevant by controllers. In the situation where STAR and Common Workspace assisted controllers, 93% of clusters expected were created. For 75% of these clusters a directive or a differed order was selected and 63% of those directives or differed orders have been delegated to STAR. In terms of workload, the tools available allowed to controllers to manage without any difficulty the traffic load.

The Common Workspace has fully played its role during the experiments; controllers have almost no spoken between them, and have perfectly completed their tasks. This shows that they were able to find in the Common Workspace all information they needed to carry it out.

The experimentations have emphasized that the tools given, have favoured the anticipation of controllers, improving the accomplishment of control objectives. However this anticipation has been increase by the absence of simulation of adjacent sectors. Sure enough, the PC was release of the management of coordination with the adjacent sectors, and have an entirely liberty to change the level of entry or exit of aircraft. This excess of anticipation has allowed PC to act on traffic and aircraft in order to reduce the number of conflicts. The workload of EC has been artificially reduced. Similarly, the "overinvestment" of PC, made possible, has led to reducing uncertainty about flights. The impact on the workload of the EC has been reduced.

The module STAR has proved unsuited to the practice of the EC. Indeed, the calculation methods used provide a trajectory avoiding the aircraft at the meadows of the standard separation and returning to the original trajectory in the shortest. This tool does not include additional factors introduced by controllers such as a safety margin above the separation distance (15NM), a deviation rate (heading) comfortable (<30 °), an anticipation of unstable aircraft. The controllers were then disconcerted by the efficiency of STAR. In addition, taking into account the unstable aircraft (changing flight level) by STAR was not optimal, as is the concept of "interfering" aircraft (aircraft that the system considers necessary to take into account to solve the conflict, and in many cases an unstable aircraft). The controllers do not seem to have this notion of interference, for them an aircraft is in the conflict or it is not. The fact that STAR adds systematically these aircraft in clusters is in contradiction, in unfavourable way, with the representation of controllers.

3.3 AMANDA V3

The objectives of this new study are about the integration of adjacent sectors and improvement of trajectory calculation. This integration consists of an extension of principles accepted in actual Common Workspace to the Planning Controllers of adjacent sectors.

- This new common Workspace will facilitate the negotiations between sectors; allow visualizing quickly the flight concerned by negotiations. This way, the workload, the time necessary, and the risk of ambiguity are reduced.
- The new common Workspace will allow to share between sectors: changes in the trajectory of aircraft, which should help to reduce uncertainty about the positions and conditions of entry for flights in a sector.

Simultaneously a study will be conducted in order to enrich the module for calculating, STAR, to improve its similarity with the practices of conflict resolution of controllers. STAR will propose trajectories similar to those controllers to promote their acceptance and limit the disconcerting effect which they can introduce. A specific study will focus on the status accorded to unstable aircraft by controllers.

By adding the notion of adjacent sector we make therefore evolve the decision, it came out of the sector. It is therefore necessary to analyze and integrate in a coherent manner the decisions inside the sector and those outsides. All this is going to require a decision making model that we now see.

3.4 Approach

The study is divided into three phases. The first phase focuses on analysis and structuring the decision-making process. Several questions ask here. First of all, an analysis of PC coordination decisions with adjacent sector is required. But these decisions must be made in coherence with the PC decisions of internal management of his/her sector. They must be brought into coherence with the internal management of the sector by EC. This phase will result in the description of a coherent process control decisions. We approach this phase in section 4.1.

The second phase is methodological order. It aims to structure each decision of decision-making process. A general methodological framework must be sought to promote coherence of each decision in view of their links with the decision-making process. Several participants contribute to the decision; each according to his/her owns value system. The methodological framework must also allow organizing exchanges between the various participants in the decision. It should also help identify, represent and manipulate the different value systems of the participants. We describe this phase in section 4.2

The third phase is classic in the field of decision support, it is the modelling phase. It aims to identify and structure the elements allowing design tools to aid decision makers. It is therefore necessary to collect the decisions elements handled by controllers. Let us note here that controllers are not the only holders of these elements. Staffs of Air Navigation responsible for the training of controllers have a favourable position in this phase. It is the same with “decision engineer”, designers of tools present in AMANDA. However air traffic controllers are the only ones who can make validation judgments of model (through the results they produce). We present this phase in section 4.3

4 Structuring of problem

4.1 Decision-making process

Control decisions exist on a continuum. At the most complete level, they are to change the trajectory of the aircraft by applying adjustments to flights parameters of aircraft in order to resolve a conflict situation operationally. The EC has in charge this operational level, and he/she can cooperate with STAR.

Previously, these operational decisions have been prepared by the PC who has information before EC. The PC may already identified a conflict situation and inform the EC at the good time. This latter will integrate this new situation in the management of his/her traffic. He/she will specify the preparation of PC to be able to operationalize later. The EC occupies a central position in the tactical level in collaboration with the PC. The Common Workspace constitutes a co-operation help between controllers. The EC also has the possibility of cooperating with STAR in this tactical management.

Finally, at the sector level, the PC is the first to have available information about flights which preparing to pass in the sector. The PC gets a strategic vision of potential conflict situations. The common workspace enables him/her to explain this vision and to capitalize so that the EC could exploit. In the context of this strategic management, PC may come into contact with adjacent sectors with in order to change flights levels of entry or exit of aircraft to avoid a conflict in his/her sector and thus reduce preventively the workload of EC. The common workspace is therefore quite naturally an area of strategic management between PC, coherent with the tactical management by the synthetic vision it presents.

We study these three axes as independently as possible with the aim of obtain refined results and focused results on a specific problem, and therefore provide the opportunity to deepen each level. But the axes are interconnected; indeed designs a trajectory without having problems is somewhat surprising. It is thus quite logically, that appeared influence between axis 1 and 2 and between axis 2 and 3. The existence of operational decisions quickly appears plausible in the current state of our thinking. Such decisions are a direct link between the axis 1 and the axis 3. We take advantage to this study to conclude about this possibility.

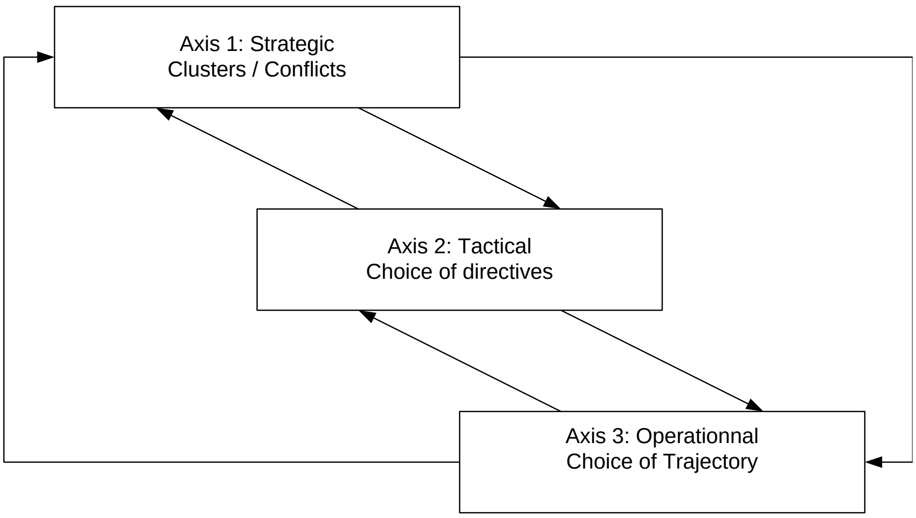

Figure 1 Synthesis diagram of three axes of the study, and the links between them.

4.2 Multiple criteria methodology

The job of an air traffic controller is characterized by the search for a compromise between different value systems. This is typically the concept of managing flows aircraft. As a result, the controllers take action on the traffic by ensuring optimal security, while trying to reduce delays and costs for fuel. ATC is by nature multiple criteria. It is quite unrealistic to summarize the action by controllers in a single goal would be safety, the cost or time. In addition, the actions of the controllers are part of a terminal management control situations. They therefore result of decisions taken previously by controllers. Therefore, it seems appropriate to discuss the design of aid in terms of Multiple Criteria Decision Making (MCDM).

The MCDM methodology [13] replace the concept of decision as result of the wider concept of the decision-making process in which several participants can play a role in their own interests. For that reason, the study of decision-making problem is itself accentuated.

The MCDM methodology proceeds in four levels (figure 2). The first level is clearly to define the potential actions. The potential actions are all possibilities (real or fictitious) on the basis of which the decision is made. The criteria are the factors (witness of the decision) which characterize the potential actions for decide. Preferences are a set of rules by which we connect the potential actions across criteria. Finally, level 4 is the determining of a recommendation. This is the operational level of the methodology, the implementation.

The study of three axes independently will therefore lead to conduct three MCDM, thus defining three problematic, obtain three families of criteria… But the recommendations (level 4) will most certainly it more comprehensive. For example during cooperation between PC, the strategic level, the PC can be lead to justify his/her requests, the operational level. In any case, it will result of these three studies only one cooperative system, a single platform. This platform will be composed of different decisions, tools different responding and corresponding to each of the recommendations and axes, but they will be grouped within a single environment, Common Workspace. We therefore deliberately choose to place the design of a decision support under consideration of process-oriented rather than result-oriented (pure performance of each tool separately). We develop a cooperative system. It should be easily usable and understandable by the Human who will have to use it.

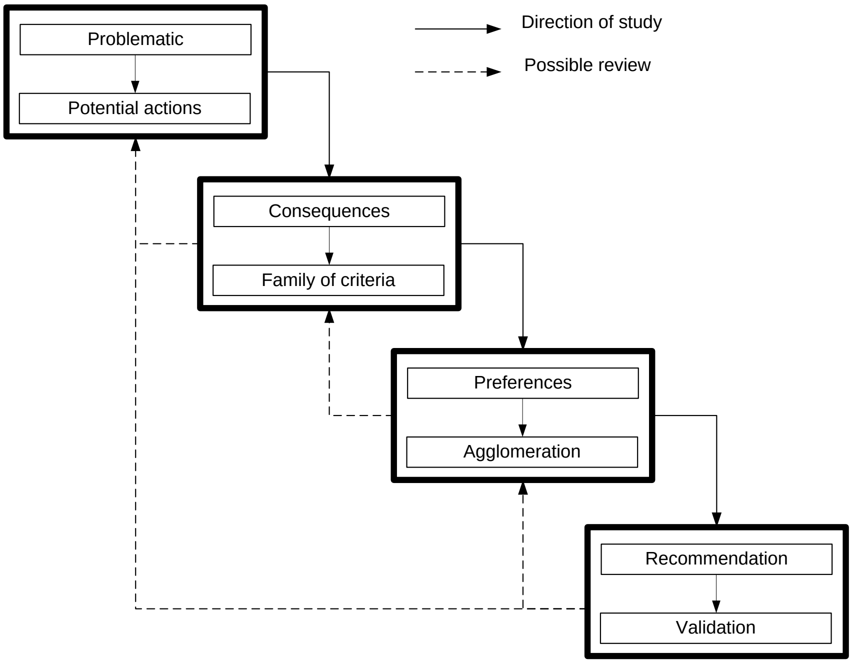

Figure 2 Synthesis diagram of the Multiple criteria Decision Making methodology (MCDM).

Human Machine Co-operation aspect is the unifying thread of the study, but we not focus especially on this point. This aspect takes place essentially in the level 4, recommendation. The main objective is to understand the steps and use that the controllers do of adjacent sectors, their manner of cooperate… Human Machine Co-operation aspect can thus considered as a synthesis of MCDM.

4.3 Repertory grid

Repertory grid is a methodology developed by an American psychologist, Georges Kelly (1955) [14], in order to study the psychological construct in pathological case (schizophrenia…).

This method will allow compare « elements » (different event, actions, states or entities). To do that, the method will « force » subject to ask him/her and thus determine a list of « constructs », as exhaustive as possible. The constructs are divided in two groups: the similarities and contrasts. Each construct (similarities or contrasts) will be then evaluated or weighted in function of the different elements of the grid. The elements, the constructs, and the weighting will represent the « construct map » of the subject.

To elicit the constructs, the « triad method » is commonly used. The subject is confronted with three elements and asked to consider ways in which two are alike but different or opposite from the third. Table 1 shows the typical representation of a repertory grid. Elements are in columns and with the triad method the subject elicits the constructs. The two poles of the constructs are written on the left side (similarity) and the right side (contrast). Then the subject is invited to complete the weight. If an element matches the left side pole it is rated with 1; if it matches the pole on the right side it is rated with 5. If an element falls in between then a rating in the range 2 to 4 is given. If the subject chooses 3, that mean that it is not the left side, and the right side, for the subject it is impossible to choose which side, it is indifferent.

<table>
<tr><td></td><td colspan="4">ELEMENTS</td><td></td></tr>
<tr><td rowspan="5">Constructs, Similarities</td><td></td><td></td><td></td><td></td><td rowspan="5">Constructs, Contrasts</td></tr>
<tr><td></td><td colspan="2" rowspan="2">Weight</td><td></td></tr>
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Table 2 Standard representation of repertory grid

The repertory grid is operational support to the MCDM. The important points of the MCDM are in the repertory grid. Notably for potential actions (clusters for axis 1, directives for axis 2, and the trajectories for axis 3) of the MCDM can be found as part of the grids, it is the elements, columns of the grid. The constructs or repertory grid can be equated with the “elementary consequences” of MCDM.

The MCDM start with a number of elements, the potential actions. For grids, which we will submit to the various participants, we take this principle into pre completing the grid with elements from the results and experimental situations of AMANDA V2, which is added any hypothetical (fictitious) situations (that the controllers did not chosen). These hypothetical situations can be "real" (potentially executable by the controller) or "unreal" (impossible choice by controllers) in order to bring a maximum of reaction. This notion of "real fictitious" and "unreal fictitious" is a concept important to the MCDM [13].

The different levels of preferences are reflected in the weights of the repertory grid. Thus weights 1 and 5 correspond to a preference strict (no doubt), 2 and 4 for a preference low (the choice is made, but less reliable), and finally a weighting 3 corresponding to an indifference (both elements are equal) or incomparability (none of the three previous levels of preferences).

We made the choice to divide the overall problem detection / resolution of the conflict in three axes. Three axes that we will try to study independently. We will therefore apply three MCDM, and hence at least a grid repertory for each MCDM [15]. These three grids are interrelated. They explore the decisional construct of controllers for each axis of decision-making process (Figure 1), and form continuity in the management and resolution of air conflicts. The elements, or potential actions, situations, focusing on the conflict, refined at each grid.

We make the choice to prepare the grids by building on experiments AMANDA V2, and especially the results, and the situations, resolutions that the various pairs of controllers can have undertaken. We begin to the review that for a specific conflict, controllers have sometimes acted very differently, offering other aircraft to take into account in clusters, different solutions to solve the conflict, a different way to use the tools. We will try to understand these differences, which in any case it leads to solving the problem.

During experiments AMANDA V2 all data were recorded, that means that we are able to replay that the controllers had to do (create clusters, directives and deviation of aircraft, use of interfaces…). We will use these data in order to identify interesting cases, and to use them for interviews with various participants (controllers, instructors, but also "decision engineer", in our case designers of experimental situations) in the form of a grid repertory. By interesting case means for example, if the reactions of controllers were different: the creation of cluster, or in the choice of a directive or a trajectory to be applied. This analysis of the results we therefore provided a number of cases which can then be submitted in the first time to the "decision engineers", which will try to understand the actions of controllers and we explain post, and especially with another viewpoint. The results of these grids are then subjected to operational controllers, which validate our findings, and our models.

5 A first decision model

In basing on the results of experiments AMANDA V2 we build a whole of grid, in presenting to participants interviewed a variety of elements that they will be analyzed. These elements are the potential actions related to the studied axis. In the case of the axis 1 (conflict detection, clusters), we look for conflicts-type on the sector, or conflicts which have aroused among controllers varied and different responses. The first grid (Table 3) is based on both a conflict fairly typical for the sector (here Bordeaux), and for which the responses of controllers are all different.

BAL632 KLM1884	BAL632 KLM1884	BAL632 KLM1884	BAL632 KLM1884	BAL632 KLM1884
AFR1657	BCS1080	AFR1657 BCS1080	AFR1657 AEL2789	

Table 3 Repertory grid proposed to the subject

In this grid, the first row is the “basic conflict” that means, it is these two aircraft that are directly in conflict, not separated by the minimal distance of separation. In the second row, there is aircraft added by controllers. They added these aircraft because for them they will intervene, restricting the manner to resolve the "basic conflict". This is typically the usefulness of clusters; display all aircraft to take into account for the resolution. The first column refers to the conflict "created" for the experimental phase. It is this conflict that designers expected, in theory, from the controllers.

We propose this first grid to a « decision engineer », who is one of the designers of the platform, and who has created the experimental situation. He known relatively well the sector and its configuration, and have a good expertise of the job.

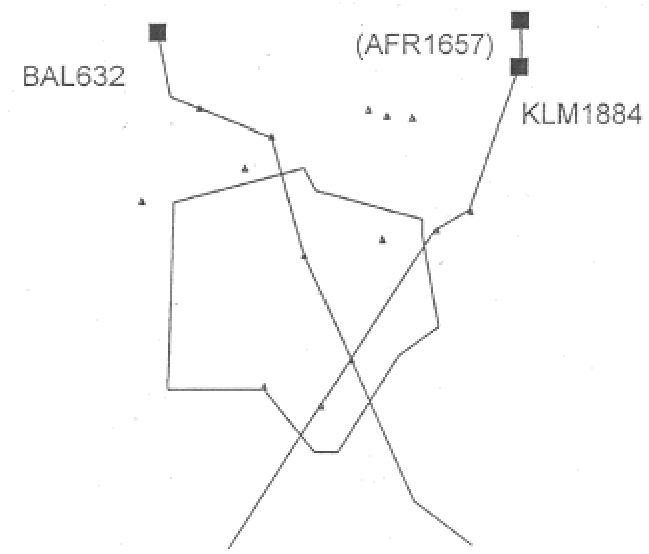

Figure 3 Schematic view of the conflict

The first key point is the variety of responses from different pairs of controllers during the experiments. But one thing in common which is the subject of the first comment is the presence whenever of the "basic conflict" between BAL632 and KLM1884 that will intersect with less one nautical mile on the beacon "VELIN".

The second construct proposed by the subject interested in the presence of the AFR1657, considered contextual in the scenarios creation, i.e. can not engage directly in the conflict, but to take into account for a resolution. Indeed as noted by the subject, controllers do not risk rerouting the BAL632 between KLM1884 and AFR1657. They would consider the distances not respected. Let us note the accuracy of STAR which is able to determine a trajectory doing this, without violating the norms of separation. For the subject, the AFR1657 is therefore essential in the conflict because it forced strongly trajectory BAL632. For him the fact that he is not here in some clusters does not mean that controllers do not take it into account, but they exclude certain resolutions can be problematic. It appears that controllers have an idea of how they will resolve the conflict, before the creation of the cluster.

The third constructs proposed is the case of BCS1080, which is an unstable aircraft (changing Flight Level). In other words, it will necessarily come to pass flight level 350, where the conflict is. The controllers did not bring under control the rate up (or down) of aircraft. These rates depend on many parameters (requests from local companies, the pilot of the aircraft, weather conditions…). In the same way that AFR1657, BCS1080 will therefore constrain future trajectory of BAL632. Half of the pairs have added this aircraft, and have decided to rise very early so that it does not interfere with the trajectory of BAL632 (subject that the pilot was soon too). This requires anticipation for instruction on BCS1080, maybe even upstream sector, and therefore coordination. The other pairs felt that the aircraft was not a problem, because he had enough time to climb, and not interfere with the trajectory of BAL632. For them the BCS1080 is possibly another conflict, but does not disturb it. It can be assumed that they still supervising the evolution of the aircraft in order to be sure that BCS1080 is on level 360 before crossing the trajectory of BAL632.

Finally the fourth construct proposed by the subject is the case of AEL2789. The AEL2789 only included in a single cluster. It is true that its involvement in the conflict is not obvious because it is relatively far from the aircraft. However, it must be taken into account if the controller chose to reroute the AFR1657 to put behind BAL632. In this case the AFR1657 closer to the AEL2789 and should supervise the distance between this two aircraft. For other pairs, for which a deviation on the AFR1657 was not envisaged, the AEL2789 was no problem, and had no reason to be included in the cluster.

Similarities	BAL632 KLM1884 AFR1657	BAL632 KLM1884 BCS1080	BAL632 KLM1884 AFR1657 BCS1080	BAL632 KLM1884 AFR1657 AEL2789	BAL632 KLM1884	Contrast
BAL632-KLM1884 Basis conflict	1	1	1	1	1	Absence of BAL632-KLM1884 => conflict cancelled by « double direct trajectories »
AFR1657 constrained the BAL632	1	5	1	1	5	AFR1657 take into account for the resolution, but not included in the cluster
BCS1080 constrained on the trajectory of BAL632 => Anticipation	5	1	1	5	5	BCS1080 is another conflict. It is not a problem for this conflict
AEL2789 in conflict only if action on AFR1657	5	5	5	1	5	AEL2789 no particular problem with this flight, in this configuration

Table 4 Result of first repertory grid

The first thing we learn, and that is important is the fact that controllers already have a fairly accurate idea of how they will resolve a conflict even before creating the cluster. This "knowledge" of the solution is very decisive for the choice of aircraft to be taken into account. Depending on the strategy already determined, controllers therefore choose only the aircraft that will be a problem in the implementation of their strategy for resolving the conflict. This is therefore clearly a link between the axis 2 and the axis 1 of the decision-making process (Figure 1)

From this first grid can already extract criteria, which are subject to confirmation with other grids and validated with controllers. The first criterion is that to be in a cluster the aircraft must really be a problem and have an involvement towards the resolution strategy that controllers have imagined. The case of AFR1657 in the grid above, taken into account by 3 of pairs

The second issue concerns the unstable aircraft (here BCS1080). The controllers do not bring under control these aircraft, and their trajectories. So an important criterion will be the anticipation. Anticipating an unstable aircraft can make it reach its level before it is a problem with a conflict (by 2 pairs it does so, and no considers the BCS1080 as embarrassing). But this anticipation takes time, and a reasonable workload, and involves coordination in most cases. This can become difficult with the increase of traffic, and could see more regularly a lot of unstable aircraft in clusters.

This first application of our approach allows confirming a number of points, and to become familiar with the conduct of interviews using repertory grid. Firstly, it is interesting to note the conclusions that can be achieved from a single grid. This is very encouraging for our approach to multiple controllers, and we are therefore confident about the results we will obtain. This will allow us to explore the work of the controllers in more detail as possible in order to take into account all aspects of their activities in the platform AMANDA.

Secondly we can learn lessons on how to conduct the grids and particularly on the protocol. It must first properly prepare the manner of presenting the repertory grid. That's mean presenting all aspects of the grid (elements, constructs) explaining what is expected from the interviewees. It must also present the completion of the grid (weighting). In example, the subject has used weighting 1 and 5, which means that there is no ambiguity between the side "similarity" and the side "contrast". But the repertory grid allows expressing these differences; including using weights 2 or 4, meaning that the element moves closer to the similarity or contrast, but with a much lower weighting 1 or 5. There is the same weighting 3.

6 Conclusion

This article begins with an introduction of Air Traffic Control and presents the problematic, which is the increase in air traffic, and limits of operators who will be unable to maintain an optimum level of safety.

The second part presents the platform AMANDA developed in the laboratory, which is intended to help controllers in their work, only on one controlling position for the moment. The platform is composed of two main tools: A module for calculating trajectory, as well as delegation of tasks (STAR), and a space of cooperation between the controllers and the tool, called Common Workspace. Thanks to these tools, controllers can cooperate more efficiently, and to discharge a portion of the activity (the calculation and application of trajectories) to manage new aircraft. These tools have been tested with professional's controllers and have obtained encouraging results. These results lead to the new version, AMANDA V3 who is the centre of this article. The objectives of this new version are presented at the end of the second part, and they concerned particularly the introduction adjacent sectors.

The third part concerns the establishment of an approach to model the new interface AMANDA V3. This approach is divided into three points, the first which aims to model the decision-making process of controllers, and then we present the MCDM that will lead the study. In the last point, we present the repertory grid methodology, which will serve of operational support to the MCDM, and support to realize the extraction of knowledge. Finally a final section presents an initial decision model, and application of the approach to an axis of our decision-making process

The continuation of the study will be to achieve other grid on three axes, in order to obtain as much information as possible, and to determine a set of criteria and preferences of the decision model that may have controllers. This work will be done largely with decision engineers, who are also the designers of the platform. Then we have to validate all the criteria and preferences with operational controllers.

Acknowledgments

We want to thank the DGAC/SDER/DTI for their financial support. We also thank all the personnel of the ATC, which by its availability and its collaboration made it possible to develop, and to evaluate the various platforms.

References

[1] DGAC, Direction générale de l'aviation civile, contrôle des routes du ciel. http://www.aviation-civile.gouv.fr/html/actu_gd/routciel.htm

[2] S. Debernard, S. Cathelain, I. Crévits, T. Poulain (2002). AMANDA Project: Delegation of tasks in the air-traffic control domain. M. Blay-fornarino, A-m. Pinna-dery, K. Schmidt, P. Zaraté (Eds.), *Cooperative Systems design*, IOS PRES, pp. 173-190, janvier.

[3] B. Guiost, S. Debernard, T. Poulain, P. Millot (2004). Supporting Air-Traffic Controllers By Delegating Tasks. In IEEE-SMC 2004, The Hague, The Netherlands, pp 164-169, September.

[4] F. Vanderhaegen, I. Crévits, S. Debernard, P. Millot, (1994). Human-machine cooperation: Toward activity regulation assistance for different air traffic control levels. International Journal on Human-Computer Interaction. Vol. 6 N° 1, January-March 1994. pp. 65-104. Salvendy, Smith, Oshima. Ablex Publishing Corporation (Eds.), Norwood, New Jersey.

[5] M-P. Lemoine, S. Debernard, I. Crévits, P. Millot (1996). Cooperation between Humans and Machines: First results of an Experiment with a Multi-Level Cooperative Organisation in Air Traffic Control. Computer Supported Cooperative Work: The Journal of Collaborative Computing; N°5 pp299-321. Kluwer Academic Publishers, The Netherlands.

[6] I. Crévits, S. Debernard, F. Vanderhaegen, P. Millot (1993). Multi level cooperation in air traffic control. Fourth International Conference on Human-Machine Interaction and Artificial Intelligence in Aerospace, Toulouse, France, September 28-30.

[7] M.R. Endsley, D.B. Kaber (1999). Level of automation, effects on performance, situation awareness and workload in a dynamic control task. Ergonomics, Vol. 42(3), pp. 462-492.

[8] M.R. Endsley (1996). Automation and situation awareness. In R. Parasuraman & M. Mouloua (Eds.), Automation and human performance: Theory and application, Mahwah, NJ: Lawrence Erlbaum Associates, pp. 163-181.

[9] M.-P. Pacaux-Lemoine, S. Debernard (2002). A common work space to support the Air Traffic Control. Control Engineering Practice, A journal of IFAC, 10, pp 571-576.

[10] B. Guiost, S. Debernard (2007). Common Work Space or How to Support Cooperative Activities Between Human Operators and Machine: Application to Air Traffic Control. Don Harris (Eds.), 12th International Conference on Human-Computer Interaction, 13, Springer, Beijing, P.R. China, Juillet. ISBN 978-3-540-73330-0

[11] R. Bentley, T. Rodden, P. Sawyer, I. Sommerville (1992). An architecture for tailoring cooperative cooperative multi-user displays. Presented in Conference proceeding of 4th Computer – supported cooperative work, Toronto, Canada, pp. 187-194.

[12] B. Guiost, S. Debernard, T. Poulain, P. Millot (2006). Task Allocation In Air Traffic Control Involving A Common Workspace And A Cooperative Support System. *IFAC ASBHS 2006*, Nancy, France, mai.

[13] B. Roy (1996). Multicriteria Methodology for Decision Aiding. Kluwer. London

[14] GA. Kelly (1955). The psychology of personal constructs. New York: Norton.

[15] R. Scheubrein, S. Zionts (2004). A problem structuring front end for a multiple criteria decision support system. Computers & Operations Research 33, pp.18-31.