

# Analysis of a Collaborative Decision Making Concept in Air Traffic Management: an Airline Perspective

*Lorenzo Castelli<sup>1</sup>, Elio Padoano<sup>2</sup>, Paola Pellegrini<sup>1</sup>, Andrea Ranieri<sup>1</sup>*

<sup>1</sup> *Dipartimento di Elettrotecnica, Elettronica ed Informatica, Università di Trieste,  
Via A. Valerio 10, 34127, Trieste, Italy*

<sup>2</sup> *Dipartimento di Ingegneria Meccanica, Università di Trieste,  
Via A. Valerio 8, 34127, Trieste, Italy  
email:{castelli, padoano, ppellegrini, aranieri}@units.it*

## Abstract

SESAR is the program aiming at the modernization of the Air Traffic Management infrastructure in Europe. Its target concept is centered around the notion of Business Trajectory. It will evolve out of a layered Collaborative Decision Making process. The CATS project was launched in November 2007 for studying a possible practical implementation the Business Trajectory. It is based on the definition of a Contract of Objectives, i.e. an agreement of the main Air Traffic Management actors on 4D intervals called Target Windows. They must be used by aircraft and guaranteed by airports and air navigation service providers in order to achieve punctuality at destination. In this paper, the opportunity of implementing the new concept is analyzed from an airline point of view. The Analytic Hierarchic Process is used for comparing the situation in which CATS is implemented with the business-as-usual one. The results achieved indicate that the introduction of the new concept of operations is the preferable option.

## 1 INTRODUCTION

The Single European Sky ATM Research Programme (SESAR) is the ambitious program aiming at the modernization of the Air Traffic Management (ATM) infrastructure in Europe. It constitutes the technological dimension of the Single European Sky initiative, launched in 2004 by the European Commission to restructure national organizations of airspaces. This will be achieved by a consolidation of air traffic services provision and a modernization of the ATM infrastructure that will provide the capacity required by the steady growth of air traffic volumes. To achieve the technological innovation and the elimination of fragmentation, SESAR adopts a top-down performance-driven approach with four high level objectives: enabling a three-fold increase in capacity, improving safety by a factor of 10, reducing by 10% the environmental impact per flight, cutting ATM costs by 50%. The SESAR definition phase started in 2005 and was completed in 2008 with the delivery of the ATM master plan (SESAR Consortium 2008). It identifies the technological steps and the modernization priorities necessary for implementing the new ATM Target Concept (SESAR Consortium 2007). This Target Concept

is centered around the innovative notion of Business Trajectory, which formally represents an airspace user's intention with respect to a given flight. The ATM services will be organized in order to guarantee that this trajectory is carried out safely and cost efficiently within the infrastructural and environmental constraints. Business Trajectories will be expressed in 4 dimensions (latitude, longitude, flight-level and time) and will evolve out of a layered Collaborative Decision Making (CDM) planning process, mainly developed in two different phases: flight preparation and execution phase. The flight preparation phase may start several months before the day of operation: the flight is defined according to the airline schedule and specific resources are assigned to it (aircraft type, crew, network resources, ecc.). On the day of operations the flight is executed as close as possible to this plan and all deviations are managed to minimize their impact on the entire schedule.

To formalize the Business Trajectory concept, the CATS project was launched in November 2007, co-founded by the European Commission Framework Programme 6, with the objectives of developing and assessing a possible practical implementation of the Business Trajectory, namely the Contract of Objectives (CoO). The CoO is a formal and collaborative commitment of ATM actors, i.e., airspace users, airports and air navigation service providers (ANSPs), to the conduction of each flight. It establishes the actors' roles and tasks, with the ultimate target of achieving punctuality at destination. 4D intervals called Target Windows (TWs) are agreed in the CoO: They constitute milestones to be met during the flight execution. The definition of TWs as intervals rather than precise points provides the means of managing the uncertainty naturally arising in real world operations, while remaining at the same time in accordance with the established local objectives. The process of determination of the TWs to be included in each CoO takes the form of a negotiation among actors. It runs in parallel with the Business Trajectory development phases, and reflects all known constraints, such as punctuality at destination, runway capacities or congested en-route areas that the flight will cross. The room for adaptation provided by TWs to air traffic controllers (ATCOs) operations, should ensure resilience to disruptions, while guaranteeing that only necessary constraints are imposed. The divergence of the actual flight with respect to the planned CoO during the execution phase is still possible, and triggers a specific decision process called renegotiation.

The CoO concept proposed in the CATS Project is expected to introduce several benefits to the the main ATM actors (airlines, airports and ANSPs). This paper focuses on the airspace users' perspective. Airlines may reduce delay-related costs and optimize their aircraft utilization, due to the higher punctuality at destination introduced by the concept. Moreover, airlines can indicate their economical and technical constraints in the negotiation, thus including their preferences in the decision process. Aircraft shall fly as close as possible to its Business Trajectory, which is built taking into account preferred routes based on economic considerations.

To analyze the opportunity of implementing the CATS concept from an Airline point of view, we perform a formal assessment of its benefits and drawbacks with respect to the business-as-usual scenario, i.e. the scenario in which the ATM system continues to develop according to the historical way of doing business. The evaluation is performed by means of the Analytic Hierarchy Process (AHP) methodology (Saaty 1990, 2000).

The AHP was proposed in the 1970's (Saaty 1977, 1980), and in the last decades it has become a widely applied method for dealing with multi-criteria decision making. Its main strength is the ability of coping with the intuitive, the rational and the irrational, when decision mak-

ers face decisions which involve several aspects, some of them uncertain, and with any number of alternatives. The AHP allows to incorporate both qualitative (intangible) and quantitative (tangible) aspects in the analysis of a complex problem: it helps to solve systematically a complex decision problem by representing it as a hierarchy of elements (criteria and alternatives); pairwise comparisons are made to synthesize the priorities of elements. For what air transportation is concerned, various problems have been considered in the literature. Among the others: McGibbon & Goodchild (2001) aimed at allowing optimized trajectories to be selected depending on aircraft operators' preferred procedures. Tsai & Su (2002) used AHP for assessing the political risk associated with the development of an air hub. Yoo & Choi (2006) focused on passport security checks at airports, while Chang et al. (2006) considered the management of dangerous goods transportation faced by air-transport-related sectors in Taiwan. Safety issues were considered by Liou et al. (2007), Zhijun & Wen (2008), and Chen et al. (2009). Otamendi et al. (2008) proposed a hierarchy for evaluating different R&D projects. Liou & Tzeng (2007) applied the AHP for evaluating airline service quality. Finally, Berritella et al. (2009) developed an application to rank the operating cost components of full service and low cost airlines.

The remainder of this paper unfolds as follows. Section 2 introduces the AHP models upon which the benefit assessment is based and Section 3 analyzes the results. Finally, in Section 4, some conclusions are drawn.

## 2 TWO AHP MODELS

The airline decisions in the flight preparation and execution phases, as well as their impact on operations and costs, are of different type and magnitude, and are, then, evaluated separately through two AHP models: At the end of the preparation phase a set of TWs is agreed by all involved actors, and the flight is ready to be operated in the execution phase. In this context, the analysis is performed considering only recurrent benefits and drawbacks though, clearly, some costs are implied in the initialization of any new process: in this sense, some investments may need to be done for introducing the CoO/TW concepts, such as those involved in the purchase of new equipment or in the adaptation of the organization; furthermore, some training shall be needed for the human resources. Nonetheless, such initial investments are not included in the analysis, as they are not attributable exclusively to the CATS implementation, but rather to the general implementation of the new ATM target concept foreseen by SESAR.

The validation of the hierarchy layouts, the definition of the preference relations between criteria, and the identification of the impact that each alternative has on the various elements, have been performed with the support of two Air France Consulting experts.

The two models proposed share some common characteristics: in both cases the alternatives considered are “implement CATS” *versus* “business-as-usual”; the goal is the maximization of the airline utility, defined as the difference between positive and negative impacts. It is worth noting that the objective is not expressed in monetary terms, since the nature of some of the elements is hardly economically quantifiable: On the one hand, the utilization of the main resources involved can be, at least in some intuitive part, translated into costs; on the other, the main benefits are intrinsically intangible. Hence, a direct comparison between the relevance of resources utilization – such as the equipment operating costs – and of benefits – such as the

increase of predictability of the system – may come up to be somehow incoherent. In this sense, more meaningful preference relations can be defined by decomposing the overall goal into use of resources and benefits.

## 2.1 Flight preparation phase

First of all, the AHP model proposed for analyzing the flight preparation phase (Fig. 1) is reported. For ease of visualization the alternative-nodes are not represented in the figure. Ideally, all the nodes for which children are not identified are connected to such alternative-nodes.

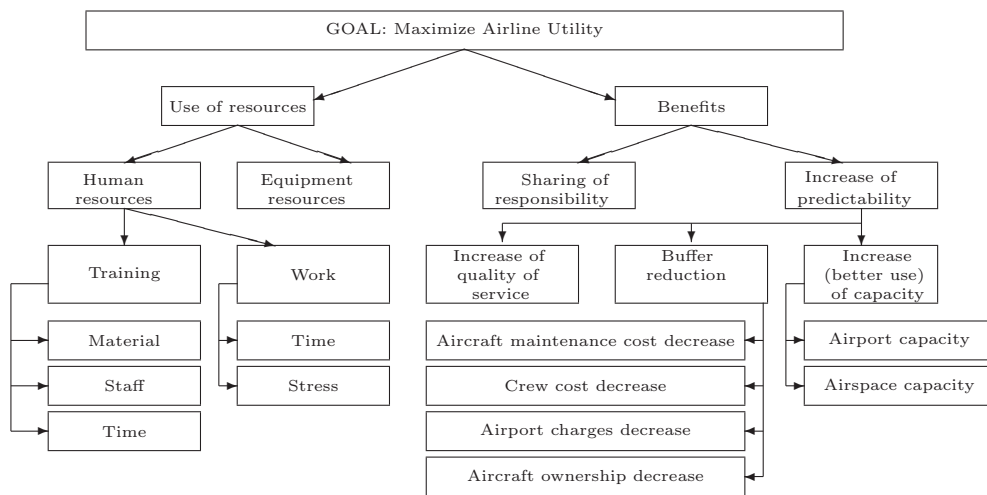


Figure 1: AHP model for the flight preparation phase

On the side of the utilization of resources, during the process of flight preparation an airline exploits some equipment and human resources. As investment activities are out of the scope of this analysis, only operational costs are considered. In this framework, the human resources impact can be split into training and actual fulfilment of the working activities: whatever the process at hand, some refreshers courses are predicted, and some staff members are devoted (totally or partially) to its daily implementation. The resources allocated to training may be further divided into material, time and staff. In parallel, the ones devoted to the working activities may be split into time and stress.

On the benefits side, the main drivers identified are the sharing of responsibility in the management of the whole system, and the increase of predictability of the traffic. The latter may be considered in terms of increase of quality of service, increase (or better use) of capacity, and scheduling buffer reduction. This element pertains to the buffer that is associated to the turnaround time required to refuel, reload and clean an aircraft in case it is scheduled for another flight once got to the airport: in general, some buffer is introduced in order to account for the possible delay of the first landing, and for limiting, in this way, the reactionary delay (Cook et al. 2004). As it will be seen in the model proposed for the execution phase (Fig. 2), an increase of predictability is foreseen to reduce delay; the time included in the buffer for coping with it may, then, be reduced, thus allowing a better exploitation of the fleet. According to Cook et al.



from getting off a plane to leaving the airport. Terminal curb and parking are also considered (Brunetta et al. 1999). Owing to an increase of predictability, a better use of such resources may be possible, in terms, for example, of luggage handling and personnel. Further, the increase of predictability implies the reduction of variability. It can be substantiated in three contexts: flight duration, in-block time, taxi time. In particular, a reduction of the variability of taxi time arises from the reduced aerodrome congestion. The consequent benefit is a reduced operating cost, resulting from operating the aircraft for a shorter period (EUROCONTROL EXPERIMENTAL CENTRE 2005). The better use of ground resources implies benefits in terms of increase of cost efficiency, and of reduction of reactionary delay. The latter allows an increase of the quality of the service. The reduction of variability, in the last three categorizations, can be subdivided into reduction of ATFM and reactionary delay (Cook et al. 2004). ATFM delay is defined as the difference between the Take-Off time scheduled for the aircraft and the Take-Off slot given by the Central Flow Management Unit (CFMU) of EUROCONTROL. Reactionary delay corresponds to the knock on effect from other delays. The benefits connected to both of them can be decomposed into reduction of ordinary maintenance and crew cost, reduction of fuel consumption, and increase of quality of the service. When considering the reduction of in-block time variability, only the crew cost and the quality of service are taken into account, since in this phase an aircraft does not move.

### 2.3 Expert judgments

Given the hierarchies presented above, the priorities among criteria are investigated. Then, the action to undertake is selected on the basis of the preference relations identified, and on the impact of the alternative decisions on each element. Here the analysis is performed relying on the support of two Air France Consulting experts: their judgments on some relevant comparisons are briefly discussed and commented in this Section. A preference scale is used for the comparisons: for each pair of criteria to evaluate, first it is to be stated which one is preferred, then the magnitude of such a preference is to be declared.

In the flight preparation phase, an interesting comparison concerns the training of human resources: one expert indicated a slight preference for favoring the quality, and then the cost, of the training staff with respect to training time, while the other expert suggested the opposite relation. The different points of view, nonetheless, do not affect the results: the recurrent training implied by CATS concept was stated to be equivalent to the one necessary in the business-as-usual scenario. The priorities assigned by the experts in all the other comparisons were equal, only in some cases the magnitude of the preference differed slightly.

According to the investigation performed, in the flight preparation phase the implementation of the CATS concept of operations does not have a relevant impact on the use of resources. The only cost slightly increased by the introduction of the CoO-based system is the cost for work. This is due to the fact that some effort will need to be devoted to the negotiation of the constraints to be considered in the definition of TWs, as introduced in Section 1. The impact of the new procedure, instead, is clearly visible on the benefits: the sharing of responsibility in the management of the whole ATM system is strongly improved, and it is considered preponderant with respect to the increase of predictability. A further improvement is envisaged in terms of increase of quality of the service. The other criteria are not significantly impacted.

For what the execution phase is concerned, instead, the implementation of the concept of operations proposed implies a slight increase of the requirement of resources. Benefits increase as well: as in the preparation phase a strong gain in terms of sharing of responsibility is foreseen; for almost all the other benefit drivers, the introduction of CATS offers a slight advantage. More in detail the improvement of quality of service is considered to be slightly less relevant than the cost reductions in most of the comparisons; the reduction of ordinary maintenance and crew cost is generally as relevant as the reduction of fuel consumption. In the execution phase the increase of predictability is considered slightly more relevant than the sharing of responsibility: the benefits implied by predictability during the actual aircraft operations are much more significant than during the flight preparation. This disparity may be due to the different immediateness of the impact of the criteria. In fact, the quantification in monetary terms of elements such as the reduction of fuel utilization or of crew cost is quite easy, and it influences positively the judgments. The same does not hold for the increase of capacity of the airspace, which is quite hard to interpret as an immediate gain for the airline.

### 3 RESULTS

In the flight preparation phase, the alternative “implement CATS” results to be the most advantageous. In the execution phase its attractiveness is even stronger. Saaty’s scale (Saaty 1980) is typically used for describing the magnitude of the preference relation identified. It consists in using a scale from 1 to 9 for the comparison, where 1 means that the alternatives are equivalent, and 9 that the predominance of one of the choices is very strong. On this scale, “implement CATS” is favored against “business-as-usual” with a rate around 3 in the flight preparation phase, and around 6 in the execution one.

The preference assigned to the implementation of CATS appears very robust. Fig. 3 reports the sensitivity analysis for the priorities of the first two levels of the flight preparation phase hierarchy: benefits *versus* use of resources, human resources *versus* equipment, and increase of predictability *versus* sharing of responsibility. On the horizontal axis, the priority of the criteria considered is reported. On the vertical axis, the attractiveness of the alternatives are represented in the interval  $[0, 1]$ . The vertical dotted line represents the preference indicated during the interviews and considered in the model. As it can be observed, business-as-usual becomes the selected option only if the use of resources is considered as strongly preferred to benefits (Fig. 3(a)). Even in this case, only an extreme value in favor of resources implies the reversal of the alternative ranking. In Fig. 3(b) and 3(c), instead, despite the difference of priorities of “implement CATS” (CATS in the figures) and “business-as-usual” (b-a-u in the figures) decreases, the former remains always preferable. Results in the execution phase are even more robust.

According to the judgments, the impact of the alternatives is often quite similar. The only strong difference concerns the sharing of responsibility: “implement CATS” has a strong positive impact on this criterion when compared to “business-as-usual” (Fig. 4). On the horizontal axis, the effect of the impact of the alternatives is described. On the vertical axis, the preferability of the alternatives are represented in the interval  $[0, 1]$ . The vertical dotted line represents the priority assigned during the interviews and considered in the model. It can be noted that in

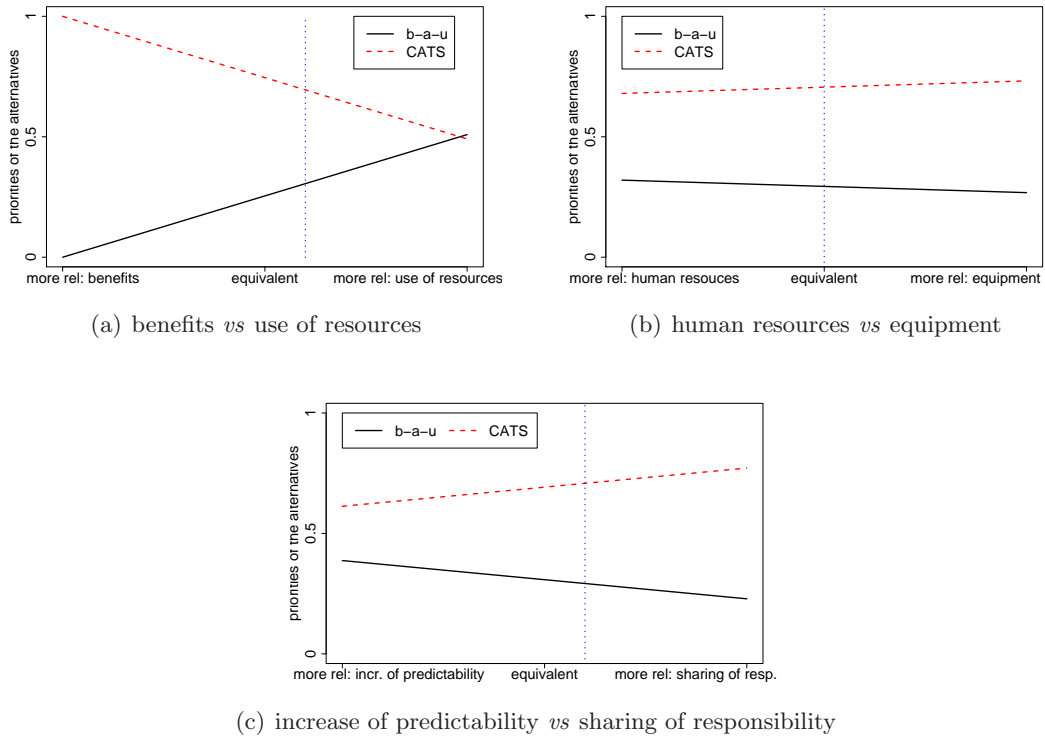


Figure 3: Sensitivity analysis for the priorities of the criteria at the first two levels (flight preparation phase).

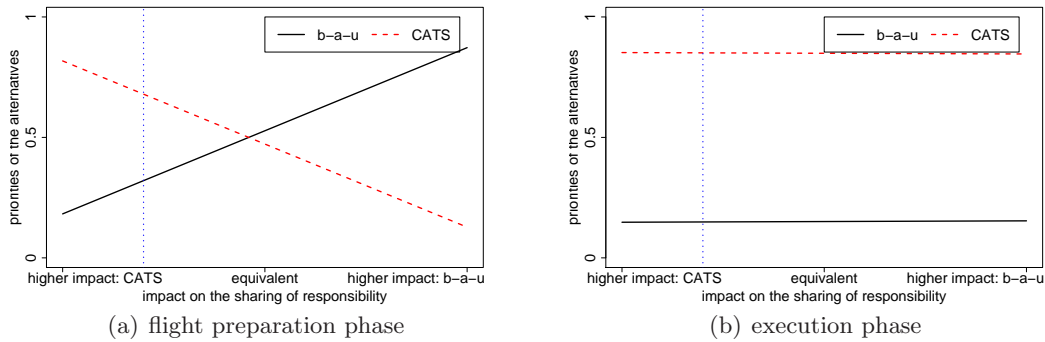


Figure 4: Analysis of the effect of the impact of the alternatives on the sharing of responsibility.

the flight preparation phase the preference relation defined is crucial to the result: the predominance of the implementation of the new concept of operations is ensured only if it implies an improvement in the sharing of responsibility. It has to be remarked, in this context, that this

element is one of the main motivations for the implementation of any CDM protocol. In this sense, the result just described was expected. In the execution phase, instead, the priorities associated to these criteria are not so relevant, since most of the benefits are recognized to be higher with the implementation of CATS than with the business-as-usual scenario.

## 4 CONCLUSIONS

This paper analyzes the potential benefits and limitations of implementing a specific Collaborative Decision Making process among airlines, airports and air navigation service providers in the framework of the European Air Traffic Management. The target of the proposed concept is to identify a set of 4D intervals (latitude, longitude, flight-level and time) called Target Windows to be met by each flight during its execution to guarantee punctuality at destination. The Target Windows are supposed to be defined prior to flight departure by means of a negotiation mechanism among all actors. By focusing on an airline point of view, we present two distinct Analytic Hierarchic Process models to evaluate the tangible and intangible effects of the introduction of these agreed Target Windows in the flight preparation and execution phases, respectively. Air France Consulting representatives have been interviewed for validating the hierarchies proposed and identifying the priorities among the various criteria. In comparison with the business-as-usual way of performing Air Traffic Management operations, the implementation of the new protocol appears to be the preferable choice, and this result is very robust. Further research will be devoted to the application of the same type of analysis to the other main actors: airports and air navigation service providers.

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## References

- Berrittella, M., La Franca, L. & Zito, P. (2009), ‘An analytic hierarchy process for ranking operating costs of low cost and full service airlines’, *Journal of Air Transport Management* . In press.
- Brunetta, L., Righi, L. & Andreatta, G. (1999), ‘An operations research model for the evaluation of an airport terminal: SLAM (simple landside aggregate model)’, *Journal of Air Transport Management* **5**, 161–175.
- Chang, Y.-H., Yeh, C.-H. & Liu, Y.-L. (2006), ‘Prioritizing management issues of moving dangerous goods by air transport’, *Journal of Air Transport Management* **12**(4), 191–196.
- Chen, C.-C., Chen, J. & Lin, P.-C. (2009), ‘Identification of significant threats and errors affecting aviation safety in Taiwan using the analytical hierarchy process’, *Journal of Air Transport Management* . In press.

- Cook, A., Tanner, G. & Anderson, S. (2004), ‘Evaluating the true cost to airlines of one minute of airborne or ground delay’, University of Westminster for Performance Review Commission (EUROCONTROL).
- EUROCONTROL EXPERIMENTAL CENTRE (2005), ‘Airport CDM. Cost Benefit Analysis (CBA)’.
- Liou, J. J. & Tzeng, G.-H. (2007), ‘A non-additive model for evaluating airline service quality’, *Journal of Air Transport Management* **13**(3), 131–138.
- Liou, J. J., Tzeng, G.-H. & Chang, H.-C. (2007), ‘Airline safety measurement using a hybrid model’, *Journal of Air Transport Management* **13**(4), 243–249.
- McGibbon, F. & Goodchild, C. (2001), Autonomous aircraft operations to managed airspace transfermanagement tool (t-mat), in ‘Digital Avionics Systems, 2001. DASC. The 20th Conference’, pp. 7B2/1–7B2/10 vol.2.
- Otamendi, J., Pastor, J. M. & García, A. (2008), ‘Selection of the simulation software for the management of the operations at an international airport’, *Simulation Modelling Practice and Theory* **16**, 1103–1112.
- Saaty, T. (1977), ‘A scaling method for priorities in hierarchical structures’, *Journal of Mathematical Psychology* **15**, 234–281.
- Saaty, T. (1980), *The Analytic Hierarchy Process*, McGraw-Hill, New York, NY, USA.
- Saaty, T. (1990), ‘How to make a decision: The Analytic Hierarchy Process’, *European Journal of Operational Research* **48**, 9–26.
- Saaty, T. (2000), *Fundamentals of the Analytic Hierarchy Process*, RWS Publications, Pittsburgh, PA.
- SESAR Consortium (2007), *Milestone Deliverable D3: ATM Target Concept*.
- SESAR Consortium (2008), *Milestone Deliverable D5: The SESAR Master Plan*.
- Tsai, M.-C. & Su, Y.-S. (2002), ‘Political risk assessment on air logistics hub developments in Taiwan’, *Journal of Air Transport Management* **8**(6), 373–380.
- Yoo, K. E. & Choi, Y. C. (2006), ‘Analytic hierarchy process approach for identifying relative importance of factors to improve passenger security checks at airports’, *Journal of Air Transport Management* **12**(4), 135–142.
- Zhijun, W. & Wen, P. (2008), ‘Application of gray evaluation model based on AHP in ATM system’, *Journal of Electronics (China)* **25**(3), 428–432.