A THEORETICAL ASSESSMENT OF SECTOR CAPACITY IMPROVEMENT DUE TO ASAS CONCEPT

Introduction

In this paper, we assess the impact of the ASAS concept on the sector capacity. By taking advantage of the new sharing of information between the ground and the airborne side, together with the provision of airborne separation capabilities, the ASAS concept envisages the transfer of some separation assurance tasks to the flight crew [1].

Even prior to prototype development, our feeling is that some assessments must be made so as to determine expected benefits of this new concept. So, the need for quantitative evaluation methods exists.

This paper focuses only sector capacity benefits expected from airborne conflict resolution. The approach that has been taken is based on the fact that although exact quantitative relation for sector capacity is not known, the trends have to be clearer. The assessment is carried out using sector capacity models which have already been developed during the past.

Sector capacity modeling

The MBB (Messerschmitt Bölkov Blohm) model was developed during the sixties. This model is described in [2,3], and also in the French air traffic services manual [6]. According to this model, sector capacity is defined as the minimum between the capacity of the planning controller and the capacity of the tactical controller.

Planning controller capacity

In the refined simplified MBB method, the sector is represented by a multi-server queue with markovian arrivals and service times:

```
Waiting line: n aircraft  S flight strips
1/\lambda  time  1/\mu  time
```

The inter-arrival times of the incoming traffic to the waiting line is assumed to follow an exponential distribution with parameter \( \lambda \), which is the average incoming traffic rate on the sector. In other words, one plane enters the sector every 1/\( \lambda \) minutes on average. The greater \( \lambda \) is, the larger the capacity of the sector is. The service time is also assumed to follow an exponential distribution where the parameter \( \mu \) is equal to the inverse of the average life duration of a strip in the sector. If \( \bar{T} \) is the average time spent by an aircraft in the sector and \( \bar{T}_e \) the average extra life duration of a flight strip in the air traffic controller strip board, then:

\[
\frac{1}{\mu} = \bar{T} + \bar{T}_e \quad (1)
\]

The job of the planning controller is to structure flight strips, and to perform the co-ordination between the previous and the next sector. From the planning controller point of view, the sector capacity is limited by the maximum number of flight strips he is able to handle.

It is assumed that the planning controller performs properly his job provided that he has to deal with less than \( s \) flight strips during more than \( p \% \) of his duty period. In others words, the safety is not affected provided that the probability of having more than \( s \) strips in the sector is less than \((1-p)\%\).

If \( N \) is instantaneous number of strips in the sector, the safety is not affected if:

\[
P(N \geq s) \leq 1 - p = q \quad (2)
\]

The sector capacity limitation due to the planning controller, which is denoted \( \lambda_{\text{strip}} \), is achieved when this inequality becomes identity:

\[
\lambda_{\text{strip}} = \arg \{ P(N \geq s) = q \} \quad (3)
\]

The probability \( P(N \geq s) \) is a general result on M/M/s queue, that is to say multi-server queue with markovian arrivals and service times [4]:

\[
\begin{align*}
\pi &= \psi \left( 1 + \frac{P(N \geq s)}{s - \psi} \right) \\
\psi &= \frac{1}{\lambda - \psi} \quad (4)
\end{align*}
\]

where:

\[
\begin{align*}
p_0 &= \frac{\psi - \lambda}{\lambda} \\
\psi &= \frac{A}{\mu} - \frac{1}{\mu} \quad (5)
\end{align*}
\]

In those equations \( \pi \) is the average number of aircraft in the sector.
Numerical simulations show the following results:

<table>
<thead>
<tr>
<th>P(N≥21)=5%</th>
<th>P(N≥22)=5%</th>
<th>P(N≥23)=5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ψ=13.8</td>
<td>ψ=14.6</td>
<td>ψ=15.4</td>
</tr>
<tr>
<td>π = 13.9</td>
<td>π = 14.7</td>
<td>π = 15.5</td>
</tr>
</tbody>
</table>

**Tactical controller capacity**

According to the previous model, the parameter $\psi$ is known when the probability $P(N≥s)$ and the number of strips $s$ remains are settled. Consequently for a given $\psi$, and knowing that $\lambda_{\text{strips}}=\psi \mu$, it implies that if the average service rate $\mu$ increases, the sector capacity $\lambda_{\text{strips}}$ increases in the same proportion.

![Graph showing sector capacity and average service rate](image)

Experience shows that air traffic controllers can not handle with an incoming traffic rate greater than $\lambda_{\text{workload}}$.

$\lambda_{\text{workload}}$ models the job of the tactical controller, which is to give clearances to the pilot. Those clearances are more or less complex, depending on the fact that the flight is scheduled or not, is steady or not, needs conflict resolution or not, and so on. All those factors are integrated in a coefficient named sector complexity. Consequently, from the tactical controller point of view, the sector capacity decreases when the sector complexity increases.

Several methods can be used to assess the safe incoming traffic rate $\lambda_{\text{workload}}$:

- In the MBB method [6], $\lambda_{\text{workload}}$ is linked to the average time that the tactical controller needs to deal with one aircraft, which is denoted $1/\lambda_{\text{workload}}$. The average service rate $\mu_{\text{workload}}$ is defined as:
  \[ \mu_{\text{workload}} = \frac{Q}{\sum k_i \cdot p_i} \]  
  (6)

  where $Q$ is the air traffic controller average hourly work capacity, $k_i$ the complexity factors for the category of traffic number $i$, and $p_i$ the proportion of category of traffic number $i$.

  According to [5], the categories and the complexity factors are the following:

<table>
<thead>
<tr>
<th></th>
<th>Without conflict</th>
<th>With conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>steady traffic</td>
<td>$k_s=1.0$</td>
<td>$k_s=2.4$</td>
</tr>
<tr>
<td>Traffic in evolution in the same airspace layer</td>
<td>$k_s=1.24$</td>
<td>$k_s=2.64$</td>
</tr>
<tr>
<td>Traffic in evolution between two airspace layers (FIR and UIR)</td>
<td>$k_s=1.62$</td>
<td>$k_s=3.02$</td>
</tr>
</tbody>
</table>

The air traffic controller average hourly work capacity $Q$ is based on the hypothesis that the time he spends on the frequency to deal with a steady traffic without conflict is equal to half of the time he spends to control this traffic [2]. If $\bar{t}_{\text{av}}$ (unit of work) is the average time spent by an air traffic controller to deal with a steady traffic without conflict, $\bar{t}_{\text{freq}}$ the average time spent on the frequency to deal with the same traffic, and $\alpha$ the ratio between $\bar{t}_{\text{av}}$ and $\bar{t}_{\text{freq}}$, then $Q$ can be defined as:

\[ Q = \frac{1}{\bar{t}_{\text{av}}} = \frac{1}{\alpha \cdot \bar{t}_{\text{freq}}} \]  
(7)

Studies conducted in Germany [6] showed that a controller spent $\bar{t}_{\text{freq}} = 32.3$ sec per aircraft. Therefore, knowing that $\alpha=2$, $Q$ can be estimated by:

\[ Q = \frac{1}{2 \cdot 32.3} = 55.7 \text{ aircraft/hour} \]  
(8)

In practice, the tactical controller can not handle the average service rate during a long time.

The safe incoming traffic rate $\lambda_{\text{workload}}$ is then defined as 60% of the average service rate $\mu_{\text{workload}}$. Hence:

\[ \lambda_{\text{workload}} = 0.6 \cdot \mu_{\text{workload}} = 0.6 \cdot \frac{Q}{\sum k_i \cdot p_i} \]  
(9)

According to this approach, the controller is viewed as a server in a single server queue, and aircraft are viewed as customers to be serviced.

- In the refined simplified MBB method [5], $\lambda_{\text{workload}}$ is defined as:

\[ \lambda_{\text{workload}} = \frac{500 \text{ aircraft} \cdot \text{minutes} / \text{hour}}{\sum k_i \cdot p_i \cdot \bar{t}_i} \]  
(10)

where $k_i$ is the complexity factors for the category of traffic number $i$, $p_i$ the proportion of category of traffic number $i$, and $\bar{t}_i$ the average duration of
flights in the category number \( i \). If \( n_i \) is the number of flights of category of traffic number \( i \), and \( n \) the total number of flights, then \( p_i \) and \( \bar{t}_i \) can be defined as:

\[
p_i = \frac{n_i}{n}, \text{ where: } n = \sum n_i \quad (11)
\]

\[
\bar{t}_i = \frac{\sum t_{i,j}}{n_i}
\]

The numerator of the formula can be found by assuming that the average time spent by an aircraft in a sector is equal to 15 minutes: 0.6 Q 15 minutes = 501.3 \( \pm \) 500 aircraft minutes/hour.

**Sector capacity**

According to the previous results, the sector capacity \( \lambda_S \) is defined as:

\[
\lambda_s = \min \left\{ \lambda_{\text{wips}}, \frac{\mu}{\bar{t} + \bar{t}_s}, \lambda_{\text{continued}} \right\} \quad (12)
\]

Let us define the sector complexity as:

\[
\text{sector complexity} = \sum k_i \cdot p_i \quad (13)
\]

Then, the general curve describing the sector capacity versus sector complexity is the following:

**Sector modeling**

**Average number of aircraft in the sector**

Let us assume that the feeding of each route in the sector follows an exponential distribution, with an arrival rate denoted \( \lambda_{Sp} \). Then, the total arrival rate for the sector is:

\[
\lambda_s = \sum \lambda_{Sp} \quad (14)
\]

If \( \bar{t}_j \) is the average time that aircraft on route \( j \) are in the sector, then the average number of aircraft in the sector due to route \( j \) is \( \lambda_s \cdot \bar{t}_j \), and the average number of aircraft in the sector is:

\[
\lambda_{ \text{sector}} = \sum \lambda_{Sp} \cdot \bar{t}_j \quad (15)
\]

If all routes have the same average sector transition time, \( \bar{t}_j = \bar{t} \quad \forall j \), then:

\[
\lambda_{ \text{sector}} = \sum \lambda_{Sp} = \bar{t} \sum \lambda_{Sp} = \bar{t} \lambda_s \quad (16)
\]

**Average number of aircraft in conflict in the sector**

Let us define \( \Phi(t) \) as the average conflict rate for one aircraft. We assume that \( \Phi(t) \) is independent from time (that is to say that \( \Phi(t) \) is equal to \( \Phi \)). If there is an average of \( E[N] \) aircraft in the sector, each experiencing conflicts at a rate \( \Phi \), then the rate of conflicts \( \lambda_c \) seen by all aircraft is:

\[
\lambda_c = E[N] \cdot \Phi \quad (17)
\]

Assuming that each aircraft spent a time which is equal to \( \bar{t} \) in the sector, the average number of aircraft in conflict \( E[N_c] \) in the sector is:

\[
E[N_c] = \int_{\bar{t}}^\infty \lambda_c \cdot dt = \lambda_c \cdot \bar{t} = E[N] \cdot \Phi \cdot \bar{t} \quad (18)
\]

By introducing (16) in (18), we obtain:

\[
E[N_c] = \left[ E[N] \right] \cdot \frac{\Phi}{\lambda_s} \quad (19)
\]

**Sector workload intensity**

Andrews and Welch [9] defined a workload intensity measure, \( \psi_{\text{workload}} \), as:

\[
\psi_{\text{workload}} = \tau_r \cdot \lambda_s + \tau_c \cdot \lambda_c \quad (20)
\]

where:

- \( \tau_r \) is the average routine time per aircraft handled by the sector,
- \( \lambda_s \) is the total aircraft arrival rate for the sector,
- \( \tau_c \) is the average conflict resolution time,
- \( \lambda_c \) is the alert rate, that is to say the rate of conflicts seen by the air traffic controller.

Schmidt [7] suggested that \( \tau_r = 60 \) seconds and \( \tau_c = 50 \) seconds were appropriate for en route systems that he observed. Furthermore, he found that when \( \psi_{\text{workload}} = 80\% \), controllers reported that the sector had reached its maximum loading.

**Relationship between sector capacity and sector workload intensity**

According to the MBB model, and while \( \lambda_{\text{workload}} \) remains inferior to \( \lambda_{\text{wips}} \), sector capacity can be addressed by studying \( \lambda_{\text{workload}} \).

Considering the most favourable case, that is to say a sector dealing only with steady traffic, we can assess the upper bound of sector capacity. If we define \( P_c \) as the probability that an aircraft needs conflict resolution, and using the maximum incoming traffic rate \( \lambda_{\text{workload}} \) as defined in the MBB method [6], then we have:

\[
\begin{cases}
\lambda_{\text{workload}} = 0.6 \cdot \mu_{\text{workload}} \\
\mu_{\text{workload}} = \frac{Q}{k_1 \cdot \left[ (1-P_c) + k_2 \cdot P_c \right]} = \frac{Q}{1+1.4 \cdot P_c}
\end{cases}
\]

Assuming that at practical traffic densities the great majority of conflicts involves only two aircraft, the probability that an aircraft needs...
conflict resolution can be approximated by the ratio between the average number of aircraft in conflict $E[N]$ in the sector divided by 2 (because it is assumed that conflicts involve only two aircraft), and the average number of aircraft in the sector $E[N]$:  

$$P_c = \frac{E[N]}{2E[N]} \quad (22)$$

By introducing (16), (17) and (19) in (22), we obtain:

$$P_c = \frac{\lambda_s}{2\lambda_c} \quad (23)$$

Consequently, the probability $P_c$ that an aircraft needs conflict resolution can be approximated by the ratio between the average time between two arrivals in the sector, which is $1/\lambda_s$, and the average time between two pairwise conflicts (involving only two aircraft), which is $2/\lambda_c$:

\[
\text{Average time between two pairwise conflicts: } 2/\lambda_c \\
\text{Average time between two arrivals in the sector: } 1/\lambda_s
\]

Furthermore, by introducing (23) in (21), we have:

$$\mu_{\text{conflict}} = \frac{Q}{1 + 1.4 \cdot \frac{\lambda_c}{2 \cdot \lambda_s}} \quad (24)$$

Consequently, the workload intensity measure, $\psi_{\text{workload}}$, can be defined as:

$$\psi_{\text{workload}} = \frac{\lambda_s}{\mu_{\text{conflict}}} = \frac{1}{Q} \left( \lambda_s + 1.4 \cdot \frac{\lambda_s}{2} \right) \quad (25)$$

We find the same kind of formula that Andrews and Welch [9] suggested, that is to say:

$$\psi_{\text{workload}} = \tau_s \cdot \lambda_s + \tau_c \cdot \lambda_c$$

where:

$$\tau_s = \alpha \cdot \tau_{pve} = \frac{1}{Q} = 64.6 \text{ sec}$$

$$\tau_c = \alpha \cdot \tau_{pve} \left( \frac{k_s + k_h}{2} \right) \cdot \frac{1.4}{2 \cdot Q} = 45.2 \text{ sec}$$

In addition, the figures that we obtain for $\tau_s$ and $\tau_c$ are very close from those that Schmidt [7] suggested (respectively 60 sec and 50 sec).

**Sector capacity improvement due to ASAS concept**

**Flow structure hypothesis**

Let us consider a sector dealing only with steady traffic, and let us define $P_c$ as the probability that an aircraft needs conflict resolution. Using the maximum incoming traffic rate $\lambda_{\text{workload}}$ as defined in the MBB method [6], the sector capacity is defined by (21).

Furthermore, by introducing (16) and (17) in (23),

we obtain:

$$P_c = \frac{\varphi \cdot r}{2} \quad (27)$$

As in [3,9], let us assume that $\varphi$, that is to say the average conflict rate for one aircraft, is expressed by:

$$\varphi = \frac{E[N]}{V} \cdot 1.4 \cdot s_v \cdot s_z \cdot E[\Delta v]_{loc} \quad (28)$$

where $E[N]$ is the average number of aircraft in the sector, and $V$ the volume of the sector.

According to this conflict rate model, a conflict occurs whenever an intruding aircraft penetrates the volume defined as a cylinder of diameter $2s_{xy}$ and height $2s_z$ around own aircraft. If $E[|\Delta \text{v}|]_{loc}$ is the relative speed between own aircraft and an intruder, the average conflict rate for one aircraft is the volume rate swept out by own aircraft, that is to say $4s_{xy}s_zE[|\Delta \text{v}|]_{loc}$, multiplied by the volumetric density of traffic assumed to be randomly located, that is to say $E[N]/V$:

\[
\begin{array}{c}
\text{Own aircraft} \\
E[|\Delta \text{v}|]_{loc}
\end{array}
\]

\[
\begin{array}{c}
\text{Intruder aircraft}
\end{array}
\]

Within those hypotheses, we also assume that air traffic controller does not miss conflict, and that all the predicted conflict are followed by a loss of separation standard. In other words, we assume that the conflict probability (predicted loss of separation) is equal to the loss of separation probability.

Hence:

$$P_c = \frac{\varphi \cdot r}{2} \approx \lambda_{\text{workload}} \cdot \tau_{pve} \cdot s_v \cdot s_z \cdot E[|\Delta \text{v}|]_{loc} \quad (29)$$

Furthermore, by introducing (29) in (21), we obtain:

$$\lambda_{\text{workload}} = \frac{1}{a} \quad (30)$$

where:

$$a = \frac{1}{0.6 \cdot Q} = \frac{\alpha \cdot \tau_{pve}}{0.6}$$

$$b = \frac{1}{1.4 \cdot \tau_{pve} \cdot s_v \cdot s_z \cdot E[|\Delta \text{v}|]_{loc}}$$

Consequently, by solving the quadratic equation in $\lambda_{\text{workload}}$, we have:

$$\lambda_{\text{workload}} = \frac{b}{2} \quad \sqrt{1 + \frac{4a}{b^2} - 1} \quad (31)$$

The graph plotting $\lambda_{\text{workload}}$ as a function of the parameter $b$ is the following.
The purpose of this graph is to illustrate the fact that the more the ATC performance is (that is to say the higher the parameter b is), the less the increase of $\lambda_{\text{workload}}$ is.

In a more general case, if we assume that $\Phi(t)$ is independent from time (that is to say that $\Phi(t)$ is equal to $\Phi$), and that the relative velocity and the relative position between two aircraft are independent random vectors, then $\Phi$ can be derived from the Reich model [8]:

$$\Phi = \mathbb{E}[\Delta v_{\parallel}] \frac{\int f(x,y,z) \, dx \, dy + \mathbb{E}[\Delta v_{\perp}] \frac{\int f(x,y,z) \, dz \, dy + \mathbb{E}[\Delta v_{\perp}] \frac{\int f(x,y,z) \, dx \, dz}}{\mathbb{E}[\Delta v_{\parallel}]}}$$

where:

- each aircraft is surrounded by a cylindrical shape, with $2s_y$ and $2s_z$ representing respectively the diameter and thickness.
- $D_y$ and $D_z$ are respectively the surface surrounding the own aircraft in the vertical and the horizontal plane.
- $E[\Delta v_{\parallel}]_{D_z}$ and $E[\Delta v_{\perp}]_{D_h}$ are respectively the average relative vertical speed and ground speed between the own aircraft and an intruder located respectively on $D_z$ and $D_h$.
- $f(x,y,z)$ is the probability density function of the relative position between the own aircraft and an intruder, located at position $(x,y,z)$ relatively to the own aircraft.

**Expected benefit from ASAS concept**

According to the MBB model, and while $\lambda_{\text{workload}}$ remains inferior to $\lambda_{\text{strips}}$, sector capacity improvement due to ASAS can be addressed by studying $\lambda_{\text{workload}}$ variation due to ASAS.

On this curve, we can see that the expected benefit from ASAS is the reduction of the sector complexity, which implies a greater sector capacity. Nevertheless, this sector capacity improvement is limited by the flight strip limitation.

**Quantitative example**

If $r_{\text{ASAS}}$ is the proportion of conflicts which can be solved by ASAS ($r_{\text{ASAS}}$ depends on the percentage of the fleet which is ASAS equipped, on the probability of use of ASAS clearance by air traffic controllers and on the efficiency of the ASAS system), and $k_{\text{ASAS}}$ the ASAS extra cost compared to $k_1$, then $\lambda_{\text{workload}}$ as defined in the MBB method [6] when ASAS is used becomes:

$$\lambda_{\text{workload,\text{ASAS}}} = k_1 \cdot (1 - p_c) + p_c \cdot (k_2 \cdot (1 - r_{\text{ASAS}}) + k_3 + k_{\text{ASAS}})$$

That is to say:

$$\lambda_{\text{workload,\text{ASAS}}} = \frac{0.6 \cdot \lambda_{\text{workload,\text{MBB}}}}{1 + p_c \cdot 1.4 \cdot \left( 1 - r_{\text{ASAS}} \cdot \frac{k_{\text{ASAS}}}{1.4} \right)}$$

(33)

We have the same kind of formula than in the previous section:

$$\lambda_{\text{workload,\text{ASAS}}} = \frac{1}{a \cdot \frac{\lambda_{\text{workload,\text{MBB}}}}{b_{\text{ASAS}}}}$$

(34)

Where:

$$a = \frac{1}{0.6 \cdot \lambda_{\text{workload,\text{MBB}}}}$$

$$b_{\text{ASAS}} = \frac{1}{1.4 \cdot \left( 1 - r_{\text{ASAS}} \cdot \frac{k_{\text{ASAS}}}{1.4} \right)}$$

Consequently, by solving the quadratic equation in $\lambda_{\text{workload}}$, we have:

$$\lambda_{\text{workload,\text{ASAS}}} = \frac{b_{\text{ASAS}}}{2} \left( \frac{1}{a \cdot b_{\text{ASAS}}} - 1 \right)$$

(35)

The sector capacity improvement (SCI) due to ASAS is defined as:

$$SCI = \frac{\lambda_{\text{workload,\text{ASAS}}}}{\lambda_{\text{workload,\text{MBB}}}} - 1$$

(37)
As an example, let us assume that:
\[
\begin{align*}
\hat{t} &= 1/4 \text{hour} \\
\hat{s}_w &= 6 \text{NM} \\
\hat{s}_i &= 1000 \text{ ft} = 1/6 \text{NM} \\
\hat{E}\{\Delta v\} &= 400 \text{NM} / \text{hour} \\
\hat{V} &= 100 \text{NM -100NM -12000 ft}
\end{align*}
\]

Furthermore, in order to take into account uncertainties in the air traffic controller average hourly work capacity \(1/Q\) and in the complexity factors, we will assume that:
\[
\begin{align*}
1/Q = \alpha \cdot \hat{r}_{\text{pos}} = 2.32.3 \pm 20\% &\approx \alpha \cdot \hat{r}_{\text{pos}} \in [51.7 \text{ sec}, 77.5 \text{ sec}] \\
\hat{k}_i - \hat{k}_o = (2.4 -1) \pm 20\% &\approx \hat{k}_i - \hat{k}_o \in [1.12, 1.68]
\end{align*}
\]

Then, we obtain the following results for the sector capacity improvement SCI, depending on the values of the ASAS extra cost \(k_{\text{ASAS}}\), and on the ASAS applicability factor \(r_{\text{ASAS}}\):

<table>
<thead>
<tr>
<th>SCI</th>
<th>(r_{\text{ASAS}}=0.3)</th>
<th>(r_{\text{ASAS}}=0.6)</th>
<th>(R_{\text{ASAS}}=0.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(k_{\text{ASAS}}=+1.0)</td>
<td>[0.2%, 1.1%]</td>
<td>[0.4%, 2.3%]</td>
<td>[0.6%, 3.6%]</td>
</tr>
<tr>
<td>(k_{\text{ASAS}}=+0.5)</td>
<td>[1%, 2.3%]</td>
<td>[2.2%, 4.8%]</td>
<td>[3.4%, 7.5%]</td>
</tr>
<tr>
<td>(k_{\text{ASAS}}=+0.0)</td>
<td>[2%, 3.5%]</td>
<td>[4.2%, 7.5%]</td>
<td>[6.6%, 12.2%]</td>
</tr>
</tbody>
</table>

This table shows that the more applicable the ASAS concept is (that is to say the greater \(r_{\text{ASAS}}\) is), and the less complicated the clearance dealing with delegation assurance is (that is to say the lower \(k_{\text{ASAS}}\) is), the higher the increase in sector capacity is.

**Conclusion**

This paper provides a quantitative approach to assess sector capacity improvement due to ASAS concept. As the paper has shown within simplifying assumptions, the ASAS concept is a way to increase sector capacity.

However, it seems that only limited growth can be accommodated by this concept. Reasons could be that the assumptions which have been taken in order to assess sector capacity are too simple, or that the model which has been used is not adapted. In particular, the network structure of a sector does not appear in the average conflict rate for one aircraft \(\varphi\). On the other hand, even if transferring some separation assurance tasks to the flight crew induces a decrease in the air traffic controller workload, we have assumed that the monitoring task remains on the ground, which is not insignificant in term of air traffic controller workload.

Sector capacity assessment is only one part of the benefit analysis expected from the concept. More investigations are needed to prove that the conflict rate experienced by aircrews is tolerable, but also to quantify safety benefits expected from the concept.

**References**


