### RVSM4 TURKEY REAL-TIME SIMULATION

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- RVSM
- CVSM
- Transition
- Non RVSM Approved
- Sectorisation
- ROUTE scenario
- Buffer Zone
- Co-ordination
- Usability
- Controller workload

**Abstract:**
This report describes a EUROCONTROL Sponsored Real-Time simulation conducted at the ENAC premises in Toulouse-France. The main objective was to assess the impact of the transition between RVSM and CVSM on the airspace structure and ATC procedures and techniques in Turkish (Ankara) airspace. Three «transition scenarios» were tested to assess how «usable» each of them was for controllers, given the broader operational context in which transition is supposed to take place. Subjective and observational data were collected to identify context-relevant features justifying controllers’ preferences.
SUMMARY

Reduced Vertical Separation Minimum (RVSM) is an approved ICAO (International Civil Aviation Organisation) concept to reduce aircraft separation from 2000 feet to 1000 feet, between Flight Levels (FLs) 290 and 410 inclusive. The implementation of RVSM in EUR RVSM airspace will be on the 24 January 2002.

The RVSM4 simulation was the fourth Real time simulation sponsored by Eurocontrol, and was designed to study the effects of the transition to and from RVSM to Conventional Vertical Separation Minimum (CVSM).

The airspace chosen for the study was the Ankara FIR in Turkey as it provided a good interface with Tehran FIR which is a non-radar environment and is expected to remain as a CVSM environment when European RVSM is implemented.

Ankara ACC provided the Controllers for the three week simulation, which was conducted at ENAC (French school of civil aviation) in Toulouse as part of the Eurocontrol simulation partnership scheme. The three traffic samples used were 1998 recordings increased by about 40% to simulate forecast traffic levels for the year 2002.

The different Scenarios used for the study were,

1. CVSM (used as a reference scenario)
2. RVSM (the controllers first introduction to the use of 6 extra flight levels – no set procedures were given to carry out the transition)
3. RVSM using a modified Route system to facilitate transition
4. RVSM using a defined area called a Buffer Zone to facilitate transition

Scenarios 2-4 were tested to determine to what extent each of them supported controllers operations while making the transition. The results show that the transition task was possible in all of the scenarios, however, they highlighted that transition cannot be studied on its own, and a wider operational environment has to be taken into account. The main issues identified as effecting the transition task were; sectorisation, route structure, resources required, usability, coordination required and the transfer from a non radar to a radar environment.

The Turkish controllers showed a preference to the modified Route system The objective data showed that performance (defined as the management of flight level changes) in the ROUTE scenario was not penalised by the transition task and coordination was lower in the ROUTE than in the other Scenarios.

The data on controllers’ workload needs to be interpreted with caution. According to some data sources, workload in the sectors not affected by transition, was lower when using RVSM. Other sources of data show the workload ratings were slightly lower for the BUFFER and the ROUTE Scenarios than for CVSM, indicating that transition was not perceived as an additional source of workload.
ACKNOWLEDGEMENTS

The Project Team would like to thank the experts of the DHMI Turkish Aviation Administration, for their assistance, co-operation and patience during the preparation and testing phases of the simulation. Their patience and support was a major factor in the successful completion of the simulation.

The authors would also like to thank all the team of ENAC and EUROCONTROL staff who worked with them on the RVSM4 Turkey simulation. Special thanks to Jean-Marc Carnus, head of the CAUTRA Division at the ENAC, for his continuous and valuable assistance. Many thanks to all from the CAUTRA Division who gave their support throughout the study and to Bernard Arini for his special help during the on-line observations. Nicole Boudes from the CENA has given valuable input as a human factors expert to the different phases of this work.

Finally, thanks to the Turkish controllers who participated in the simulation. They all displayed a high level of professionalism and enthusiasm and it is their input that provided the results to be found in this report.
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<tr>
<td>ACC</td>
<td>Area Control Centre</td>
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<tr>
<td>AIP</td>
<td>Aeronautical Information Publication</td>
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<tr>
<td>ANT</td>
<td>Airspace and Navigation Team</td>
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<td>ARN</td>
<td>ATS Route Network</td>
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<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
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<tr>
<td>ATCO</td>
<td>Air Traffic Controller</td>
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<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
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<tr>
<td>ATS</td>
<td>Air Traffic Services</td>
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<td>CFL</td>
<td>Cleared Flight Level</td>
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<td>CVSM</td>
<td>Conventional Vertical Separation Minimum</td>
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<td>CWP</td>
<td>Controller Working Position</td>
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<td>DHMI</td>
<td>Turkish Aviation Administration</td>
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<td>ECAC</td>
<td>European Civil Aviation Conference</td>
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<tr>
<td>EEC</td>
<td>EUROCONTROL Experimental Centre</td>
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<tr>
<td>ENAC</td>
<td>Ecole Nationale de l’Aviation Civile (School of civil aviation)</td>
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<tr>
<td>EUROCONTROL</td>
<td>European Organisation for the Safety of Air Navigation</td>
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<tr>
<td>EXC</td>
<td>Executive</td>
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<tr>
<td>FIR</td>
<td>Flight Information Region</td>
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<tr>
<td>FL</td>
<td>Flight Level</td>
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<tr>
<td>FPSD</td>
<td>Flight Progress Strip Distribution</td>
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<tr>
<td>Ft</td>
<td>Feet</td>
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<tr>
<td>HQ</td>
<td>Headquarters</td>
</tr>
<tr>
<td>N/A</td>
<td>Non Applicable</td>
</tr>
<tr>
<td>Nm</td>
<td>Nautical miles</td>
</tr>
<tr>
<td>PLC</td>
<td>Planner Controller</td>
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<tr>
<td>R.T.</td>
<td>Radio &amp; Telephone</td>
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<tr>
<td>RaVM</td>
<td>Radar Video Map</td>
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<tr>
<td>RDS</td>
<td>Radar Display System</td>
</tr>
<tr>
<td>RFL</td>
<td>Request Flight Level</td>
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<tr>
<td>RHF</td>
<td>Radar Height Filtering</td>
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<tr>
<td>RVSM</td>
<td>Reduced Vertical Separation Minimum</td>
</tr>
<tr>
<td>SID</td>
<td>Standard Instrument Departure</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard Arrival Route</td>
</tr>
<tr>
<td>STCA</td>
<td>Short Term Conflict Alert</td>
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<tr>
<td>SU</td>
<td>South Upper</td>
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<tr>
<td>TID</td>
<td>Touch Input Device</td>
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<tr>
<td>TMA</td>
<td>Terminal Manoeuvring Area</td>
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<tr>
<td>TS</td>
<td>Telephone System</td>
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<tr>
<td>UIR</td>
<td>Upper Information Region</td>
</tr>
<tr>
<td>WU</td>
<td>West Upper</td>
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1. INTRODUCTION

1.1 RVSM

Reduced Vertical Separation Minimum (RVSM) is an approved International Civil Aviation Conference (ICAO) concept to reduce aircraft separation from 2000 ft to 1000 ft, between Flight Levels (FL’s) 290 and 410 inclusive.

1.2 RVSM TRANSITION

Implementation of RVSM within EUR RVSM airspace will be on 24 January 2002. Three EUROCONTROL sponsored Continental RVSM Simulations have already been carried out which have mainly concentrated on the effects of RVSM on the core area of Europe. Until RVSM4 no continental simulation had examined the effects of the transition to and from RVSM to Conventional Vertical Separation Minimum (CVSM). The EUR RVSM airspace has been defined and the Ankara UIR will be transition airspace. DHMI agreed to supply the expertise and controlling staff to perform a simulation examining the effects of transition. The choice of Turkey was particularly valuable as the ATS of the adjacent FIR to the east operated a procedural service only. The Simulation was therefore able to focus on aspects relating to the transition to and from a non-radar CVSM environment and RVSM. Ankara FIR was divided into 4 sectors, with sectors E1 and E2 effecting the transition task to the east of the FIR and within Turkish airspace.

1.3 DATA COLLECTION

The information provided in this document has been collected and collated from joint discussion and documentation provided by Eurocontrol HQ, DHMI, ENAC and EEC.

1.4 RELATED DOCUMENTS

Documents related to the project include:

- AIP Turkey
- RVSM4 Facility Specification
2. SIMULATION OBJECTIVES

2.1 GENERAL OBJECTIVE

To assess the impact of the Transition between RVSM and CVSM on the airspace structure (including sectorisation) and ATC procedures and techniques in Turkish (Ankara) airspace.

2.2 SPECIFIC OBJECTIVES

1. Investigate ATC techniques for handling traffic making the transition from an RVSM environment to a non-RVSM procedural environment and vice-versa.

2. Examine the following airspace structure issues
   - testing a revised route structure to handle transition
   - Assess the impact of a defined Buffer Zone for handling transition
   - Assess the impact of RVSM on sectorisation.

3. Further validate the RVSM ATC Procedures developed by the ATM Procedures Development Sub Group (APDSG) of the ANT. This will include:
   - RT Phraseology.
   - RVSM procedures - including the handling of non-RVSM approved traffic entering RVSM airspace which are required to descend below FL290 (or climb above FL410), and non-RVSM approved State aircraft which have to be incorporated in the RVSM area.

2.3 ACHIEVEMENT OF OBJECTIVES

The simulation analysis was achieved by careful and extensive monitoring of control positions by the Human Factors Team. The methodology was to develop a characterisation for each of the measured sectors to determine the strategies used for handling the traffic flows and why certain actions were performed at a given time within a given scenario. Some aspects of the in depth analysis included sectorisation, crossing points, safety, route flows, planning, time constraints and coordination.

3. SIMULATION ENVIRONMENT

3.1 SIMULATION AREA

The area of interest for the simulation was expressed in latitude and longitude by a lower left point and an upper right point:

(a) Lower left point 34° 00’ N 028° 30’ E
(b) Upper right point 44° 00’ N 046° 00’ E

The ANKARA FIR/UIR limits are provided in AIP - TURKEY. The description of...
these limits included navigation points positioned on these boundaries.

### 3.2 CONTROL CENTRES

ANKARA ACC was the only Centre simulated.

### 3.3 ROUTE STRUCTURE

The route structure used in the Simulation was the one in current use, but included changes foreseen in ARN Version 3.

Two revised routes were created for ROUTE scenario, which included a small additional dualized route at DASIS and a one way system entering Ankara FIR at BONAM and leaving the FIR at ALRAM.

### 3.4 METEOROLOGICAL CONDITIONS

It was possible to simulate different wind conditions during the simulation. The direction and strength of the wind was decided as necessary for each exercise by the simulation team.

### 3.5 STCA

Short Term Conflict Alert (STCA) was not available for the simulation.

### 3.6 SECTOR TYPES

The simulation area was divided into "Measured sectors" and "Feed sectors"

#### 3.6.1 Measured Sectors

Measured sectors were manned by two controllers: Executive (EXC) and Planner controller (PLC).

Measured sectors were associated with TWO Controller Working Positions (CWP).

**The Measured sectors were:**

<table>
<thead>
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<th>Sector Name</th>
<th>Sector Code</th>
<th>ACC</th>
<th>CWP</th>
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<tbody>
<tr>
<td>West Upper</td>
<td>WU</td>
<td>ANKARA</td>
<td>2</td>
</tr>
<tr>
<td>South Upper</td>
<td>SU</td>
<td>ANKARA</td>
<td>2</td>
</tr>
<tr>
<td>North East</td>
<td>E1</td>
<td>ANKARA</td>
<td>2</td>
</tr>
<tr>
<td>South East</td>
<td>E2</td>
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- 8 Total

#### 3.6.2 Feed Sectors

The primary feed task was to respond to inbound co-ordination requests and to transfer /receive traffic to/from the measured sectors. Each feed sector was manned by one Controller.
The Feed sectors were:

<table>
<thead>
<tr>
<th>Sector Name</th>
<th>Sector Code</th>
<th>ACC</th>
<th>CWPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISTANBUL Feed</td>
<td>I1, I2,</td>
<td>ISTANBUL/DALAMAN</td>
<td>1</td>
</tr>
<tr>
<td>West Feed</td>
<td>W1, W2</td>
<td>ANKARA/ANTALYA</td>
<td>1</td>
</tr>
<tr>
<td>East Feed</td>
<td>F1, F2, F3, F4</td>
<td>ANKARA</td>
<td>1</td>
</tr>
</tbody>
</table>

3.7 SCENARIOS

Four Scenarios were prepared in order to achieve the objectives.

3.7.1 CVSM scenario

The purpose of the reference CVSM scenario was to simulate the 2001 Ankara airspace, which was the sectorisation and route structure in use today with the introduction of the ARN Version 3 route changes.

The traffic sample was CVSM with 1998 traffic levels increased initially by about 30%.

Note: After a first visualisation at the ENAC, the traffic samples were increased by an additional 10-15%, by adding flights on the main routes. This resulted in an overall increase of around 40-45% compared with 1998 traffic levels to reflect the traffic load of the future in which the RVSM will be implemented.

3.7.2 RVSM scenario

RVSM SCENARIO examined the effects of the Introduction of RVSM within the ANKARA FIR. Transition to and from CVSM was required with traffic entering and exiting the Tehran FIR.

The traffic samples were RVSM with 1998 traffic levels increased the same way as the CVSM SCENARIO

Measured/Feed sectors were the same as in the CVSM scenario.

The Route network was the same as in the CVSM scenario.

3.7.3 ROUTE scenario

ROUTE scenario was the same as the RVSM scenario with the following exceptions:

A modification to the route network was made to the West of DASIS. This permitted a one way system to be used for aircraft entering/exiting Ankara FIR via DASIS. A one way system was also introduced west of BONAM using existing routes (See Annex A).

3.7.4 BUFFER scenario

BUFFER scenario was the same as the RVSM scenario with the following exceptions:
A Buffer Zone was created in sectors E1 and E2 in order to provide a specified area in which to execute transition between CVSM and RVSM.

The Buffer Zone initially passed vertically (North to South) through the crossing point of ERZ. However, after the first buffer exercise it was decided to move this western boundary some 40 Nm. east to avoid the crossing point (see Annex A).

4. TRAFFIC SAMPLES

4.1 CREATION

Three base Traffic samples were created based on traffic data supplied by DHMI from the 17/18 April 98. The samples had extra traffic added in order to simulate a realistic level of traffic planned for RVSM introduction.

The base samples will be used to create the RVSM samples, i.e. exactly the same traffic load but the CVSM flight levels being changed to RVSM flight levels where necessary. The base samples were taken from the following days.

17 April – Friday = Morning and Afternoon traffic Sample
18 April – Saturday = Weekend traffic Sample

Non-RVSM approved (Non State) aircraft were included in each exercise. (see 5 ATC WORKING PROCEDURES). The following types were considered Non RVSM – AN26, B707, E3, BA46, BE30, DC9, C650, IL76, IL86, TU34, TU54.

Non-RVSM approved State aircraft were included in each traffic sample. Only 1 Non-RVSM State flight per sector per exercise was introduced. The entry times and callsigns were varied to avoid controller familiarity.

<table>
<thead>
<tr>
<th>Number of aircraft per hour</th>
<th>Average over the CVSM, RVSM, Route and BUFFER scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MEDIUM TRAFFIC LOAD</td>
</tr>
<tr>
<td>sector</td>
<td>CVSM</td>
</tr>
<tr>
<td>E1</td>
<td>35,3</td>
</tr>
<tr>
<td>E2</td>
<td>26,7</td>
</tr>
<tr>
<td>SU</td>
<td>28,0</td>
</tr>
<tr>
<td>WU</td>
<td>45,0</td>
</tr>
</tbody>
</table>

Table 1: Traffic load
4.2 LIST OF TRAFFIC SAMPLES

The Traffic Samples used in the simulation were:

<table>
<thead>
<tr>
<th>No. A/c</th>
<th>Measured Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTNG</td>
<td></td>
</tr>
<tr>
<td>TS601</td>
<td>125 0600-0730</td>
</tr>
<tr>
<td>TS611</td>
<td>147 1200-1330</td>
</tr>
<tr>
<td>TS621</td>
<td>151 1300-1430</td>
</tr>
<tr>
<td>TS602</td>
<td>125 0600-0730</td>
</tr>
<tr>
<td>TS612</td>
<td>147 1200-1330</td>
</tr>
<tr>
<td>TS622</td>
<td>151 1300-1430</td>
</tr>
<tr>
<td>TS603</td>
<td>125 0600-0730</td>
</tr>
<tr>
<td>TS613</td>
<td>147 1200-1330</td>
</tr>
<tr>
<td>TS623</td>
<td>151 1300-1430</td>
</tr>
<tr>
<td>TS604</td>
<td>125 0600-0730</td>
</tr>
<tr>
<td>TS614</td>
<td>147 1200-1330</td>
</tr>
<tr>
<td>TS624</td>
<td>151 1300-1430</td>
</tr>
</tbody>
</table>

Table 2: Traffic sample data decode:

TTNG: Training
TS: Measured Sample

The middle number indicates whether the sample was Morning 0 (low traffic load), Afternoon: 1 (medium traffic load) or Weekend: 2 (high traffic load).
The last number in each code represented the CVSM scenario: 1, RVSM: 2, Route: 3, Buffer: 4.
5. ATC WORKING PROCEDURES

Controllers were informed of ATC working procedures before the exercises.

The ATC working procedures used during the simulation were in accordance with current Letters of Agreement and/or particular Operational Instructions.

Non-RVSM approved (Non-State) aircraft planning to enter the Measured sectors, above FL290, were required to descend to FL280 or below. It was the responsibility of the first Measured sector in Ankara FIR to ensure that the descent was carried out. The Non-RVSM aircraft were identified by a Square Radar Position symbol as opposed to a circle, and the words ‘NORVSM’ were printed on the controllers flight strip.

Non-RVSM approved (State) aircraft were permitted to enter the Measured sectors, however, 2000 foot vertical separation (or the required horizontal separation) was given against RVSM traffic whilst operating within RVSM airspace. The Non-RVSM State aircraft were identified by a Square Radar Position symbol as opposed to a circle, and the words ‘NORVSM-S’ were printed on the controllers flight strip.

During exercises involving the buffer zones, traffic Eastbound at RVSM levels were required to be level at the requested CVSM level prior to entering the defined buffer zone. Traffic entering the buffer zone from a CVSM environment made the transition to the required RVSM flight level within the buffer zone.

During all RVSM exercises traffic leaving Ankara via VESAR was denied the use of FL 350.

There were no Military control positions provided during the simulation. However, a direct Military telephone line was available on each measured sector, which was connected to the closest feed sector. This enabled the controllers to carry out co-ordination calls to a simulated military position.

R/T procedures were published separately in the Controller Handbook and were in accordance with standard ICAO practice with the addition of the recommendations of EUROCONTROL regarding phraseology for Non-RVSM aircraft.

6. OPERATIONS ROOM

6.1 LAYOUT

The room layouts (Operations and Pilots) are shown in Annex B.

6.2 FLIGHT STRIPS

Paper flight strips were used on the measured sectors.

6.3 TELECOMMUNICATIONS

All control positions were provided with a Telephone touch panel that had a direct link with all of the other sectors.
7. SIMULATION PROGRAMME

7.1 EXERCISE SCHEDULE

The simulation was completed over three weeks from 11th – 29th January 99.

The simulation briefing for participating controllers was given on the morning of Monday 11 January and was followed by training exercises which provided an initial / refreshment familiarisation with the simulation facilities in the control room. The controllers had already been issued with a controller Handbook, which explained the Simulation Objectives and technical aspects pertaining to the ENAC Simulator.

Between Tuesday 12th and Thursday 28th January, 27 exercise slots were carried out amounting to a total of 40.5 hours of measured exercises.

The final debriefing was held at 16:00 Thursday 28 January 99.

Simulation exercises were conducted on the basis of 2 exercises per day. Each exercise ran for about 1 hour 35 minutes.
8. RESULTS

8.1 INTRODUCTION

The Results section starts first with the topics that emerged throughout the questionnaires integrated by comments controllers made during the team debriefing. Then on-line observations and the performance data are presented to support and to expand on the topics identified. The objective data was compared with controllers’ statements to check for any apparent discrepancy.

8.1.1 Data Collected

The data collected came from five sources:

- Pilot/Controller performance data automatically collected and stored
- On-line observations
- Team debriefing
- General debriefing
- Questionnaires.

The five sources are described below.

8.1.2 Pilot/Controller performance data

The CAUTRA system allowed the automatic recordings of the following data for each exercise:

- The actual flight profile, including the recordings of each control action
- The traffic load
- The radio/telephone load for each sector

This data will be analysed in the second part of the Results Reporting, concerned with testing the usability of each scenario.

8.1.3 On-line Observations

In order to get information on strategies used, problem formulation, planning and coordination controllers were observed during the exercise. In particular, they were observed while working in those sectors concerned by the transition and they were asked to justify their decisions with respect to the location at which they effected the transition. This data has been integrated mostly into the «Questionnaire» Reporting, i.e., in the paragraphs 8.1.6 through 8.10.

8.1.4 Team-debriefing

After each exercise the sector-teams working in those sectors concerned by the transition, discussed with the observer (a human factors expert) the characteristics of the traffic situations and how those interacted with the transition task. These team-debriefings have been particularly useful for constructing the questionnaires. The aim was to ask questions that reflected controllers main concerns about effecting the transition in their actual environment.
8.1.5 General debriefing

After each run, before the team-debriefing, controllers had an opportunity to bring up issues concerning the exercise with the simulation team. Whenever possible their needs/requests were taken into account by the ENAC-CAUTRA Team.

8.1.6 Questionnaires.

The Table below summarizes the five questionnaires including main objectives and time at which they were distributed.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Objective</th>
</tr>
</thead>
</table>
| General questionnaire (distributed during the second week) | Assessment of RVSM  
Assessment of the transition task               |
| Questionnaire about RVSM (distributed during the last week) | Evaluate specific features of the scenario         |
| Questionnaire about Route (distributed during the last week) | Evaluate specific features of the scenario         |
| Questionnaire about Buffer zone (distributed during the last week) | Evaluate specific features of the scenario         |
| End-of-Simulation Operational questionnaire        | Compare simultaneously the different scenarios     |

Table 3: Questionnaires distributed during the three-week simulation period

General remarks about questionnaire answering

The controllers’ answers to questionnaires have been compared where possible to automatically recorded data to verify coherence between the two sources of data. If any discrepancy between subjective (controllers’ opinions) and objective (performance data and on-line observations) data is observed, it does not imply that the subjective data is unreliable. Additionally, the controllers could have envisaged a range of possible situations not included in the simulation. To fully exploit the information provided, the controllers’ answers were quantified but at the same time opinions expressed by a minority were given full consideration.

Controllers provided a rich amount of information through their written comments. They have often taken the transition task as an opportunity to discuss issues involved in their daily work. They emphasized negative aspects much more often than advantages of managing the traffic in the different scenarios. These negative aspects were not linked to the transition but rather to a number of interacting factors. For example, the constraint of transferring eastbound traffic to a non-radar environment interacted negatively with the sectorisation chosen in the simulation. They have remarked that it would be difficult to appreciate the benefits of RVSM while working with a neighboring country who lacked radar facilities.

Concerning the three scenarios proposed to effect the transition, controllers expressed a clear preference for the ROUTE scenario. That result was checked against the observational data to gain further evidence for the opinions expressed. Although some advantages were found for the ROUTE scenario, those advantages were not always very impressive. The traffic load seemed to account for the efficiency and efficacy of the controllers performance.
8.2 QUESTIONNAIRE - GENERAL

This questionnaire was distributed during the second week of testing, when controllers had experienced only the CVSM scenario. Ten questions made up the general questionnaire. Some of them (like questions I and J) were formulated as the result of extensive discussions with controllers. They reflect thus some concerns controllers have expressed during team debriefing, prior to the formulation of the questionnaire. Their written answers to the questionnaire will be integrated by comments they made during the team debriefing. The four major topics covered by the questionnaires were as follows;

- How comfortable were controllers while working with RVSM and their level of workload compared to CVSM (questions B & C);
- The quality of information on the flight strips of RVSM aircraft (question G);
- Issues concerning the handling of State and non-State, non-RVSM aircraft. Topics included workload, phraseology and procedures (questions D, E, F & H);
- Three questions were about handling the transition, transferring and sectorisation (A, I & J).
8.2.1 Level of comfort and workload with RVSM

All of the controllers felt from «quite» to «very» comfortable while working with RVSM, due to the extra flight levels (Figure 1).

![Question B: How comfortable are you when working with RVSM?](image)

**Figure 1: Distribution of answers to question B**
 Average score = 8.0 (on a 1 to 10 scale)

Similarly, 100% of the controllers felt their workload was lower when working with RVSM than with CVSM organisation (Figure 2).

![Question C: Comparing CVSM & RVSM exercises, how do you consider your workload with RVSM?](image)

**Figure 2: Distribution of answers to question C**
 Average score = 1.5 (on a 1 to 5 scale)
8.2.2 Quality of information

**Question G:** With regard to RVSM aircraft, do you consider that the information on the strip was adequate?

**Yes:** 100 %

8.2.3 Handling of non-RVSM aircraft

**Question D-1:** Has your workload increased whilst dealing with the State aircraft?

**Yes:** 100 %

- For non-RVSM State aircraft, all of the controllers felt that their workload was quite high compared to baseline. Non-RVSM State aircraft required extra attention thus decreasing the effort controllers could devote to other conflicts.

- When asked by how much, their answers ranged from «slight» to «high»

**Question E:** Did you experience any confusion between non-RVSM non-State and non-RVSM State aircraft?

**Yes:** 50%  **No:** 50 %

Some confusion was due to the fact that the track symbol on the scope was the same for non-RVSM State and non-RVSM non-State aircraft. Confusion could be avoided if:

- the planner would highlight the non-RVSM aircraft on the strips and inform the radar controller;

- the pilots always identified themselves as non-RVSM aircraft.

**Question F:** Do you consider that the phraseology for the handling of non-RVSM aircraft -State & non State- to be appropriate?

**Yes:** 100%
8.2.4 Transition, transferring and sectorisation.

The controllers felt that working with RVSM organisation was preferable to working with the CVSM organisation.

Most of the controllers found that the separation task at the Eastern boundary was slightly harder with RVSM because:

- Transitioning might generate new conflicts
- Evolving aircraft need extra attention
- Controllers might forget to effect the transition
- Flight information from Tehran might not arrive in due time or it might be incomplete. This has to be taken into account while effecting Eastbound transition.

Some controllers observed that the coupling of transition and transfer task might require the aircraft to go through many flight levels at once

**Question J**: Do you think that the boundary between E1 & E2 affected the transition task?

**Yes**: 75%  
**No**: 25%

Most of controllers found that the boundary between E1 and E2 affected the transition. This was mostly due to the airway between ERZ and VAN requiring a late inter-sector transfer.

Controllers thought that coordination between the two sectors was crucial due to the following:

- E2 has not enough time to effectively integrate traffic handed over by E1.
- Controllers thought it was difficult to find appropriate flight levels for traffic coming from E1
- The range of possible control actions was limited; for example, time/speed restriction was not applicable because aircraft coming from E1 and going into E2 sector were delivered too close to the Eastern boundary.

A proposal to alleviate the burden on E2 was that E1 would deliver to E2 aircraft already established on a CVSM level. Incidentally, this is exactly the procedure designed for the BUFFER zone scenario.

Summary of findings for the general questionnaire and discussion
The main points about RVSM and working with State non RVSM aircraft were that controllers felt:

- They were quite comfortable
- Their workload was lower than when working with CVSM
- The quality of information on the strips was good
- Their workload was higher when dealing with State non-RVSM aircraft

Controllers agreed that there would not be any confusion between non-RVSM State and non-RVSM non-State aircraft, given that:

- There was a good sector-team (Executive and Planner) coordination and the Planner would inform the Executive about the presence of a non-RVSM aircraft
- The pilots would identify themselves as non-RVSM aircraft.

Thus, while controllers appreciated working with RVSM, they felt that the separation task at the eastern boundary was slightly harder than in the actual airspace. They perceived that as an additional task besides transitioning. During sector-team debriefing, they often reported to feel constrained by the requirement to deliver eastbound traffic applying the 10-minute separation rule.

Finally, the sectorisation between E1 and E2 demanded that the planner controller from E2 coordinated with E1 aircraft delivery. If aircraft delivery was not coordinated at appropriate time and flight level, that could become an additional source of workload such as the creation of new conflicts near the boundary. On line observations confirmed indeed that during high traffic load, late inter-sector delivery generated new conflicts right near to the boundary with Tehran FIR.

8.3 QUESTIONNAIRE - RVSM SCENARIO

The questionnaire developed for the three scenarios included six questions. As for the general questionnaire, some of the questions reflected issues that controllers brought up during team debriefing.

- Three questions were about planning, coordination and sectorisation respectively between E1 and E2 (questions K, L, M)
- One question was about satisfaction when working in the different sectors (question N)
- One question was about overall workload when working in the four measured sectors (question O)
The final question allowed controllers to make any comment about each scenario (question Q).

Answers and scores to the above mentioned questions are shown in figure 4.

The identified topics were dealt with respect to the eastbound traffic in the sectors concerned by the transition. In fact for the Westbound traffic, transitioning from CVSM to RVSM and transferring from a non-radar to a radar environment, did not seem to raise any particular concern.

8.3.1 Planning, coordination & sectorisation

While answering questions about planning, coordination and sectorisation, controllers identified a number of factors making the eastbound transition and transfer tasks sometimes difficult. The main factors described are:

- The late inter-sector transferring
- The amount of flight strip output: during high traffic peak, it was difficult to integrate strips as they arrived because there was not enough time
- The 10-minute separation rule
- The availability of only two exit points for the eastbound traffic going to Tehran FIR
- High traffic load, forcing controllers to use low flight levels. Observational data concerning this point will be presented later (see 9.2.3 exit /cleared flight levels).

Some of these issues have already been raised while answering the general questionnaire. The additional comments provided by controllers about the RVSM scenario allows us to further understand how the interaction between these factors makes, in the view of controllers, the transition and transfer tasks quite demanding.

Concerning the planning of traffic from E1 while working in E2, controllers opinions went from “slightly difficult” to “difficult”.
Question K: When working in E2, how difficult is it to plan the traffic coming from E1?

![Bar chart showing distribution of answers to question K.]

**Figure 4: Distribution of answers to question K.**

Average score = 3.57 (on a 1 to 5 scale)

**Question L-1:** Was additional coordination required between E1 & E2?

*Yes:* 71%  *No:* 29%

80% of those who thought additional coordination was required, estimated that «more» to «much more» was required.

**Question M:** Does the position of the sector boundary between E1 & E2 affect the coordination required?

*Yes:* 57%  *No:* 43%

Comments provided to the above mentioned questions were:

- Planning was difficult because flight strip output was high
- The sectorisation between E1 and E2 required the traffic to be handed over to E2 when it was already quite close to the Tehran boundaries
- Sometimes during high traffic load, controllers in E2 felt they did not have enough time to plan for transition and transfer.
8.3.2 Satisfaction and workload

Questions about workload and satisfaction concerned the following sectors: E1, E2, WU & SU.

![Question N: Satisfaction with RVSM](chart.png)

**Figure 5: Distribution of answers to question N**

E1: Controllers' satisfaction went from "dissatisfied" to "satisfied" (average score = 3.3)

They expressed appreciation for getting extra flight levels.

Reasons for low satisfaction scores were:
- The high flight strip output made controllers feel that they were not always fully mastering the situation
- Changing flight level for transitioning implied checking for traffic coming from the opposite direction. Given the potential source of error, that was considered a demanding feature of the transition task environment.

E2: The level of satisfaction was lower in E2 (average score = 2.7) compared to E1: The identified factors were:
- The late inter-sector transferring from E1 to E2 affecting controllers' activities such as planning and coordination
- While E1 was mostly concerned with conflict resolution, E2 in addition had to manage transition and transfer problem. This was because most of the eastbound traffic was exiting through E2
- Given the time pressure and the traffic load, controllers felt that sometimes it was difficult to accomplish both the transition and the transfer task.

While working in the West Upper (WU) or South Upper (SU) sectors (average score = 4.6), the level of satisfaction was the highest and controllers appreciated the benefits of working with the RVSM organisation.
Concerning workload distribution, controllers ratings were moderate for E1 (average score = 6.7) and E2 (average score = 7.3). As shown in Figure 6, the workload average was lower in WU and SU (average score = 4.1) sectors than in E1 and E2 sectors.

8.3.3 Summary - Questionnaire on RVSM scenario

In the RVSM scenario, sectorisation between the two sectors concerned by the transfer/transition tasks, seemed to affect planning and coordination activities. Because traffic coming from E1 was handed over to E2 when too close to the Tehran boundary, controllers working in E2 felt under time pressure. In particular they felt they did not have enough time to integrate the new flows of traffic coming from E1. This late inter-sector transferring caused an increased need of traffic awareness concerning the adjacent sector. In addition the high flight strip output could cause E2 to revise the planning of the traffic. The amount of needed coordination seemed to depend, among other factors, from the traffic load. High traffic load contributed to a feeling of not fully mastering the situation. This seemed to be particularly true for sector E2 as reflected by the low satisfaction scores (average =2.0, «unsatisfied»).

Finally, for those sectors not concerned by the transition. satisfaction for working with RVSM organisation was high and workload was low.

8.4 QUESTIONNAIRE - ROUTE SCENARIO

8.4.1 Planning, co-ordination & sectorisation

Controllers had mixed opinions concerning how difficult it was to plan the traffic coming from E1 while working at E2 (Figure 7).
Two major sources of difficulties were:

- Several intersection points made it difficult to carry out the transfer and transition task
- Frequent need for new planning: When the strip output was high, planning of traffic coming from E1 was difficult. This point has already been raised for the RVSM scenario.

These difficulties reflect more the consequences of the traffic load than the evaluation of the particular Scenario considered.

For those who assessed planning «easy», the advantages of the Scenario Route were that the route structure allowed more time to plan for the 10-minute separation at the Tehran boundary.

**Question L-1**: Is additional coordination required between E1 & E2?

**Yes**: 57%  
**No**: 43%

Among the controllers who felt that additional coordination was required, some justified it by explaining that E2 has a higher traffic load than E1.

**Question M**: Does the position of the sector boundary between E1 & E2 affect the coordination required?

**Yes**: 29%  
**No**: 71%

A small percentage of the controllers felt that no major coordination was necessary to transfer aircraft from a radar to a non-radar airspace in this scenario.
8.4.2 Satisfaction and workload

- E1: Controllers’ satisfaction went from «unsatisfied » to «very satisfied» (Figure 8).

For those who were satisfied, the main reasons were:

- For transitioning, radar vector is not necessary in the ROUTE scenario
- Aircraft can maintain their RVSM level longer than in the other scenarios
- Route structure relieved some time pressure felt in the other two scenarios

![Figure 8: (question N) Distribution of satisfaction scores. Mean score: 3.4, mean score for E1 & E2= 3.7 (on a 1-to-5 scale)](image)

E2: Preferences changed: almost 60% of controllers were unsatisfied mostly because of the high traffic load.

WU & SU: controllers were more than satisfied.

Controllers assessed their workload to be low and it was quite the same when working in all of the sectors including those not affected by the transition (see Figure 9).
8.4.3 Summary - Questionnaire on the ROUTE scenario

The ROUTE scenario relieved the time pressure felt in the other two Scenarios. In general, the traffic load and the presence of busy traffic intersections were regarded as the main causes for needing additional coordination. Overall, sectorisation did not seem to increase the need for coordination, but it was rather the coupling of transition and transfer tasks that necessitated a good management of the available resources (i.e., coordination and planning).

The advantages of the ROUTE scenario were that:

- Controllers’ perception of the transition was safer because of unidirectional route
- During the transition radar vectoring was not necessary
- Theoretically aircraft can maintain their RVSM level longer than in the other scenarios
- Transition and transfer were eased because of unidirectional route

Some controllers remarked that the traffic load in some cases was not realistic and that made it difficult to evaluate the ROUTE scenario. Others remarked that the 10-minute separation rule made it difficult to fully appreciate the benefit of RVSM and the benefit of the solution proposed to manage the transition (Question Q).

8.5 COMPARISONS BETWEEN ROUTE SCENARIO AND RVSM SCENARIO

With respect to RVSM scenario, differences were summarized as it follows:

Planning difficulties: The distribution of answers for RVSM was closer around the score «difficult» while for ROUTE scenario the distribution was more scattered. For the last scenario, 14 % of controllers found planning «easy». Further, controllers comments about planning were always negative in RVSM scenario, while in the ROUTE scenario some advantages were also identified.

Additional coordination required: 80 % of controllers in the RVSM scenario thought
that additional coordination was required between the two sectors concerned by the transition. On the other hand, in the ROUTE scenario, more than 40% of controllers thought that additional coordination was not required.

**Sectorisation** was deemed to affect coordination by 57% of controllers in the RVSM scenario, while 43% of controllers thought so for the ROUTE scenario.

**Satisfaction** scores for the sectors concerned by the transition, were higher for ROUTE scenario (close to «satisfied» mean score 3.7) than for RVSM scenario (between «unsatisfied» and «moderately satisfied», mean score = 2.7)

**Workload** was lower in ROUTE scenario and there was no difference between the sectors concerned by the transition and those that were not. This means that in the ROUTE scenario the transition and transfer tasks were not perceived as additional sources of workload.

In RVSM scenario while workload was higher, there was also a difference in appreciation between workload in the transition sectors and in the other sectors.

8.6 QUESTIONNAIRE - BUFFER SCENARIO

Controllers tested two versions of the buffer zone. According to the initial one, later discarded, the boundary line went through a major intersection point. Because the boundary line was moved eastern after the first exercise, the questionnaire referred to the «new» buffer zone. There were three questions about sectorisation and coordination in the two sectors concerned by the transition (E1 and E2). Nevertheless, most issues were raised with reference to sector E2. Apparently the airway organisation was judged to be more penalizing for sector E2.

8.6.1 Planning, co-ordination & sectorisation

Controllers found that, when working in E2 sector, planning traffic coming from E1 was difficult or very difficult (Figure 10).

![Figure 10: Distribution of answers to question K](image)

*Figure 10: Distribution of answers to question K*

*Average score 4.0 (on a 1 to 5 scale)*
They offered the following reasons:

- Flight strips output was high and that implied a need for new planning
- In sector E2, due to the high traffic density around the major intersection point ‘GEM’, controllers were forced to clear aircraft to lower flight levels.

**Question L-1**: Is additional coordination required between E1 & E2?

**Yes**: 100%

Their remarks included:

- Coordination should be mutual between the two sectors in order to clear aircraft to appropriate flight levels before they approach inter-sector transfer point to E1 sector
- Aircraft being transferred to E2 sector should already be cleared to their CVSM level
- Coordination should be affected to a third controller.

**Question M**: Does the position of the sector boundary between E1 & E2 affect the coordination required?

**Yes**: 100%

The following observations were made:

- The traffic coming from E1 created new conflicts around the beacons VAN and UMH, which are right in the transition/transfer area.
- E2 has to solve these new conflicts and manage the transfer task in a very short time.
- The sectorisation meant that E1 had to control a large rectangular area including six intersection points. During high traffic load, monitoring these major conflict points became difficult.

### 8.6.2 Satisfaction and workload

Controllers were asked to rate their satisfaction while working in sectors concerned by the transition (E1 & E2) and in those which were not (WU & SU).
E1: More than 50% (4 out of 7) of controllers were unsatisfied (average score = 2.71)

They felt overloaded by the following tasks:

- Monitor for conflicts
- Manage the transition
- Establish the 10-minute separation before transferring traffic to Tehran
- Be ready to accommodate requests coming from E1 sectors

E2: Overall, controllers were unsatisfied when working in E2 (average score = 1.86). Major concerns expressed were:

- Traffic coming from E1 and already established on CVSM level, sometimes generated new conflicts. Controllers sometimes had to momentarily use westbound levels to solve conflicts. This situation requires a careful monitoring of the westbound traffic already established at the RVSM levels
- Traffic coming from E1 might involve a new planning of the traffic in E2. The new plan might penalize the E2 traffic in terms of moving the aircraft through many flight levels at once.

When E2 received the traffic from E1, accomplishing the transfer task might be difficult. This is because:

- Time pressure limits the range of possible control actions such as radar vector or speed restriction
- VAN was the transferring point between E1 and E2. Due to a short distance between the two beacons ERZ and VAN, controllers felt under time pressure while adjusting flight levels. In addition they expressed concern because this was a busy bi-directional route.

WU & SU: While the distribution of satisfaction score for the E2 sector was the
lowest, controllers highly appreciated working with the RVSM organisation in those sectors (WU & SU) not concerned neither by the transfer, nor by the transition tasks.

Workload ratings both for E1 and E2 sectors were quite high (Figure 12).

![Image of workload distribution chart]

**Figure 12: Distribution of answers to question O.**

Average score for E1 = 7.9, E2 = 6.7, WU & SU = 3.7 (on a 1 to 10 scale)

### 8.6.3 Summary - Questionnaire on the BUFFER scenario.

Controllers’ opinions did not always refer to the specific Scenario tested. For example, answers to planning difficulties did not include any reference to the presence of the buffer zone. Rather controllers underlined traffic load and the transferring tasks as important factors.

More generally, the major issues concerning the transition sectors in the BUFFER zone scenario were:

- A mutual need for coordination for sectors E1 & E2
- Coordination as a task, could be assigned to a third controller
- The ERZ-VAN route was a busy bi-directional route
- The amount of coordination depended, amongst other things, on the traffic load
- The airway organisation.

To solve the late inter-sector transferring problem, three controllers suggested to eliminate the airway between ERZ and VAN (in E1). Thus all of the traffic to Tehran in E1 should exit DASIS. This would probably increase workload for E1 but would relieve pressure from E2.

Some controllers suggested making the airway EZS-SRT-ALRAM (in E2) as a one-way route for eastbound traffic. This implies that BONAM should not be used as eastbound exit point. This amounts to organizing the airspace according to what has been proposed in the ROUTE scenario.
Some controllers remarked that while coordination between E1 and E2 was still necessary, the new buffer zone allowed more time to plan and solve conflicts over ERZ and to transition aircraft to CVSM levels before transferring them to E1.

The major concerns expressed about E1 were:

✦ The size of the sector implied 6 intersection points
✦ Many tasks to be carried out
✦ Establishing 10-minute separation should be done before the traffic is transferred to E2.

Concerns about E2 were based on two main issues:

✦ The late inter-sector transferring
✦ The traffic load resulted in a high output of strips in a short time interval.

The late inter-sector transferring implied the creation of new conflicts near to the Tehran borders. For this reason, some control options were reduced, such as radar vectoring and speed/time restriction. Opposite levels were used to solve late conflicts and that led to extra monitoring for potential face-to-face conflicts. Because controllers felt already busy with the transfer and transition tasks, late inter-sector transferring caused them to feel under time pressure.

When the flight strips output was high, sometimes that implied the need for a new planning (replanning). If controllers were under time pressure, they felt they did not have the time to make a new satisfactory plan integrating the late transferred traffic. Further, if coordination was poor, some penalizing solutions could be applied to solve late conflicts, such as giving low flight levels or asking aircraft to change several flight levels at once.

As a concluding remark, controllers seemed more concerned about sectorisation and traffic load than about the boundary line introduced by the buffer zone.

8.7 COMPARISONS BETWEEN BUFFER VS RVSM AND BUFFER VS. ROUTE

To conclude this chapter, results will be compared for the Buffer zone to RVSM and to the ROUTE scenarios. Five subjects will be discussed:

✦ Planning difficulties
✦ Coordination
✦ Sectorisation
✦ Satisfaction
✦ Workload

Assessments and reasons brought up by controllers are summarized in table 4. «Assessments» include not only the ratings but also the written and oral judgments. In some cases the Route and the BUFFER zone scenarios were rated quite similarly but the comments controllers made orally and in writing, emphasized some important differences between the two scenarios.
Reasons justifying controllers’ ratings were the same for BUFFER zone and for RVSM. Nonetheless the BUFFER zone seemed to be judged the most penalizing for effecting the transition.

<table>
<thead>
<tr>
<th></th>
<th>Buffer zone vs. RVSM</th>
<th>Buffer zone vs. Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning difficulties</td>
<td>Slightly higher for Buffer zone.</td>
<td>Quite higher for Buffer zone.</td>
</tr>
<tr>
<td>Ratings</td>
<td>Traffic load and late inter-sector transferring.</td>
<td>Route allowed more time to plan for transition/transferring.</td>
</tr>
<tr>
<td>Reasons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-ordination required</td>
<td>Higher for Buffer zone.</td>
<td>Much higher for Buffer zone.</td>
</tr>
<tr>
<td>Ratings</td>
<td>Late inter-sector transferring.</td>
<td>Route eliminates the late inter-sector transferring.</td>
</tr>
<tr>
<td>Reasons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectorisation</td>
<td>Quite higher for the Buffer zone.</td>
<td>Much higher for the Buffer zone.</td>
</tr>
<tr>
<td>Ratings</td>
<td>Sectorisation implied late inter-sector transferring.</td>
<td>Sectorisation implied late inter-sector transferring.</td>
</tr>
<tr>
<td>Reasons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Lower for Buffer Zone.</td>
<td>Lower for Buffer Zone.</td>
</tr>
<tr>
<td>Ratings</td>
<td>RVSM implied face-to-face conflict while transitioning and E2 had to manage transition and transfer.</td>
<td>Radar vector not necessary in the Route,</td>
</tr>
<tr>
<td>Reasons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workload</td>
<td>About the same</td>
<td>Higher for Buffer zone</td>
</tr>
</tbody>
</table>

Table 4: Differences between Buffer zone vs. RVSM & Buffer zone vs Route

8.8 END-OF-SIMULATION OPERATIONAL QUESTIONNAIRE

After completing questionnaires about making the transition in general and for each scenario, controllers answered the «Operational questionnaire». There were fourteen questions whose objectives were to compare the scenarios RVSM, ROUTE & BUFFER along several dimensions. They were:

- safety (question 1),
- need for coordination (question 2),
- easy of use (questions 3 & 4)
- user satisfaction (question 5).
- sectorisation (question 6)
Other questions asked to controllers:

- to evaluate features of each scenario (question 7, 8, 9, & 10) and
to assess how they felt about working with RVSM whether their perception and impression has changed throughout the simulation (questions 11, 12, 13 & 14).

Question 1: Which scenario do you consider the safest?
Question 5: Which scenario do you feel most comfortable working with?

Comparing safety and comfort across the three scenarios, 100% of controllers considered that the ROUTE scenario was the safest and most comfortable to work with.

Question 2: Which scenario do you think needs most coordination?

- 50% of controllers thought that BUFFER scenario zone needed most coordination,
- almost 40% of controllers (3 out of 8) thought that there was no difference among the three scenarios.

Question 6: Do you consider the dimensions of the sectors E1 and E2 appropriate?

The dimensions of sectors E1 and E2 were judged appropriate for all of the scenarios by almost all of the controllers. A suggestion was made that for scenarios RVSM & BUFFER the airspace be partitioned in smaller sectors and new exit points to Tehran FIR be established.

Question 3: Which scenario makes the transition from the CVSM to RVSM easiest?

Almost 90% (7 out of 8) agreed that ROUTE scenario makes the transition easiest.

Question 4: Which scenario makes the transfer at the Tehran boundary easiest?

50% of controllers thought that ROUTE scenario helps them in making the transfer (question 4). The other 50% thought that with respect to the transfer task, there was no difference among scenarios.

Question 7: Is there any way in which the BUFFER zone scenario could be improved?

Controllers provided the following suggestions:

- More than 60% controllers (5 out of 8) explicitly stated that the route (between beacons ERZ and VAN) causing late inter-sector transferring should be eliminated.
- The boundary line of the buffer zone was moved eastwards from its original position (see Annex A -Scenario 4). This was considered an improvement as the three extra RVSM flight levels could be used to solve conflicts around the major intersection point ‘ERZ’, that was now situated before the boundary line of the buffer zone.

**Question 8:** In BUFFER zone scenario, which sector do you consider is the most difficult to work?

Controllers essentially split into two groups:

- 50% of controllers did not find any difference between E1 and E2
- Almost 40% of controllers (3 out of 8) found that E2 was the most difficult scenario to work while
- About 10% of controllers (1 out of 8) thought that E1 was the hardest.

They made the following remarks:

- Controllers felt that they did not have enough time to accomplish the transfer and the transition tasks. This was due to the amount of traffic load and to the frequent need of making new traffic planning.
- Controllers often thought they were working in a demanding situation because of the simultaneous presence of multiple tasks. For that they suggested a need for increased flexibility in terms of release of operational constraints (10-minute separation norm, restrictions on military zone, co-ordination, ...);
- The major constraints associated with the sector E1 were the presence of several major intersection points and the proximity of the boundary line to a main intersection point;
- The main constraint associated with the sector E2 was late inter-sector transferring.

**Question 9:** In the ROUTE scenario, do you think the size of the one-way route in E1 was appropriate?

Concerning the size of the one way route in E1, 100% of controllers answered that it was appropriate.

They offered some comments concerning the ROUTE scenario:

- The route structure by eliminating the opposite traffic, gives controllers more time and space to realize the transfer and the transition tasks;
- They felt relieved from the need to monitor for potential conflicts with opposite traffic
- The only major task was to adjust flight levels to comply with transition and transfer rules.

**Question 10:** In the ROUTE scenario, which one of the one-way route system do you prefer?

Concerning preference for the one-way route, controllers split into two main groups.
- 50% preferred working with the bigger one-way route in sector E2. They stated that the one-way route in sector E2 gives them more time to accomplish transition and transferring.
- Almost 40% (3 out of 8) showed no preference. Only one controller indicated a preference for the smaller one-way route in E1.

**Question 11:** In CVSM FL 310, FL 350, and FL 390 are Westbound levels. In the RVSM exercises, these flight levels became eastbound levels. By the end of the simulation, did the reversal of these flight levels cause any problems?

Ctrls had unanimously stated that by the end of the simulation, the reversal of these flight levels did not cause any problem. They remarked that at first, the reversal of flight levels caused some confusion but after a few exercises they become familiar with the new order.

**Question 13:** Has your perception of RVSM been changed by the simulation?

Ctrls had unanimously stated that by the end of the simulation, the reversal of these flight levels did not cause any problem. They remarked that at first, the reversal of flight levels caused some confusion but after a few exercises they become familiar with the new order.

**Question 14:** What is your overall impression of RVSM?

Ctrls had unanimously stated that by the end of the simulation, the reversal of these flight levels did not cause any problem. They remarked that at first, the reversal of flight levels caused some confusion but after a few exercises they become familiar with the new order.

- Due to the transfer to Tehran, transitioning from and to RVSM became an additional task
- Transitioning required extra attention to monitor for potential conflicts especially in high traffic load conditions.
- Finally controllers all agreed that the implementation of RVSM will be beneficial for both ATCO’s and worldwide airline companies.
Question 12: What problems, if any, do you foresee regarding the implementation of RVSM?

Controllers offered the following remarks:

- The route structure is the safest and it should be used for traffic coming from Tehran
- It would be useful to test the transition/transfer task in a simulation, which includes radio/radar failure, emergency and military flights and other safety-critical conditions
- Turkey is not only a «transition area» but first of all a «transfer area». Having to manage traffic that goes into a procedural environment reduces the benefits of RVSM. A full appreciation of RVSM will be possible when the neighboring airspace is equipped with radar facilities.

8.9 SUMMARY OF QUESTIONNAIRES

Generally speaking controllers appreciated RVSM in those sectors that were not concerned by transition. Transition, on its own was not a problem, but it became a rather demanding task when coupled with:

- Transferring traffic to Tehran FIR
- The chosen sectorisation
- The flight strips output.

Controllers referred to the output of the flight progress strips and the accuracy of the estimates. Given the high traffic load, controllers heavily relied on estimates to plan the traffic. When strip output was high and estimates were not quite accurate, controllers were forced to change their planning.

A second concern was the traffic load, which was at times judged unrealistic and seemed to make difficult an appreciation of the different scenarios. All of the issues that emerged would probably not have received so much attention if the traffic load had been lighter.

8.9.1 Co-ordination

The BUFFER scenario, seemed to raise the highest number of concerns as shown in Table 5.

<table>
<thead>
<tr>
<th>Additional Coordination required between E1 &amp; E2</th>
<th>RVSM</th>
<th>Route</th>
<th>Buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>71%</td>
<td>57%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount of additional coordination (1-to-4 scale)</th>
<th>RVSM</th>
<th>Route</th>
<th>Buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1,25</td>
<td>2,29</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. a. Percentage of «Yes» to the question about coordination in the 3 transition scenarios. b. Distribution of scores for need of coordination in the 3 scenarios.
In fact, 100% of controllers agreed that additional coordination was required in the BUFFER scenario vs. 57% who expressed the same opinion in the ROUTE scenario (Table 5). On average, the BUFFER Scenario required «more» coordination while the ROUTE «slightly more» (see distribution of average scores in Table 5). Further, 43% of the controllers thought that «much more» coordination was required in BUFFER scenario, while 75% of controllers in ROUTE scenario thought that only «slightly more» additional coordination was required.

The RVSM scenario was somewhat in between the other two. An increased need for coordination both for RVSM and BUFFER seemed to be the effect of sectorisation. In fact the sectorisation chosen implied the late inter-sector transferring. Three major issues were linked to late inter-sector transferring:

- The existence of new conflicts near to the boundaries with Tehran
- E2 had to revise their previous planning
- Controllers of both sectors need to be aware of the traffic situation in each other’s sector.

Because of the proximity with the boundaries, controllers felt that little time was left to adequately plan for transferring and for solving new conflicts concerning traffic coming from the route ERZ-VAN. Controllers stated that the amount of coordination was higher in BUFFER scenario and RVSM because of the need to avoid late conflict resolution and new planning in the transition area near the Tehran FIR. In addition the route ERZ-VAN is a busy bi-directional route and being right in the transition area it increases the chance of face-to-face conflicts. Monitoring demands are therefore higher in Scenarios RVSM and BUFFER than in ROUTE scenario.

Controllers expressed a marked preference for the ROUTE scenario. They appreciated the following changes of the task environment due to the new route structure:

- The route between the beacons ERZ and VAN was eliminated and thus the late inter-sector transfer problem solved and its side effects eliminated. This meant that there were neither late conflicts nor late transfer to be done near the boundary with Tehran, which were causing controllers to revise their planning
- Controllers from E1 and E2 need not be permanently aware of the traffic situation in each other sector
- By introducing a new one-way structure, there was less chance of face-to-face conflict, thus less need for monitoring
- Consequently time pressure was reduced, giving controllers a better means to cope with transfer, transition and conflict detection and resolution.

Because the ROUTE scenario was less demanding than the RVSM and BUFFER scenarios, there was less emphasis on the need for coordination. In other words, in a less demanding situation, the need for optimal resource management strategies was less crucial.
8.9.2 Sector boundary and co-ordination

- Sector boundary affected coordination mostly in the BUFFER zone scenario, as shown in Table 17.2-1

<table>
<thead>
<tr>
<th>Does the position of the sector boundary (E1 &amp; E2) affect coordination?</th>
<th>RVSM</th>
<th>ROUTE</th>
<th>BUFFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>50%</td>
<td>43%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 6: Percentages of «YES» to the question about sector boundary and coordination

The main reason was the late inter-sector transferring. This was true for both the BUFFER and RVSM scenario. The constraint imposed by the boundary line of the Buffer zone contributed to the feeling that coordination was affected by sector boundary more heavily in the BUFFER scenario than in the RVSM scenario.

The ROUTE scenario was the least affected by the sector boundary as the elimination of the ERZ-VAN route got rid of the late inter-sector transfer issue.

8.9.3 Planning traffic coming from E1

- Planning traffic coming from E1 appeared to be easier in ROUTE scenario essentially because the late inter-sector transferring was eliminated (Table 7).

<table>
<thead>
<tr>
<th>When working in E2 how difficult it is to plan the traffic coming from E1? (on a 1-to-5 scale)</th>
<th>RVSM</th>
<th>Route</th>
<th>Buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.37</td>
<td>3.43</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 7: Distribution of average score for planning of traffic

As shown in table 7, the difference among the scenario is negligible. Controllers did appreciate the advantage of the ROUTE scenario but they found that the traffic was at times too heavy and this affected their activities independently of the Scenario.

8.10 CONCLUSIONS FROM THE QUESTIONNAIRES

To conclude, according to the kind of data analyzed so far, self-assessment data, there are a number of constraints affecting the quality of the controllers' performance. Factors such as

- time pressure
- quality of information
- late inter-sector transferring,
These factors are reflected in the medium-to-low satisfaction scores obtained. In particular, the lowest satisfaction score was for E2 in the BUFFER scenario meaning that for this scenario the above mentioned factors were particularly critical. On the other hand, the high satisfaction scores expressed for those sectors not concerned by the transition, indicated that controllers highly appreciated working with RVSM.

Concerning workload, controllers did not seem to make any remarkable differences between the scenarios. Their workload was estimated rather low while working in the sectors not concerned by the transition (WU & SU).
9. ANALYSIS OF OBSERVATIONAL DATA

In the following paragraphs the observational data will be analyzed to identify a set of indexes allowing the comparison between controllers’ activity and aircraft performance across the different scenarios. Controllers’ opinions will guide our hypothesis formulation. For example, does the observational data confirm that the BUFFER scenario was somewhat more penalizing than ROUTE scenario?

Whatever the answers obtained from questioning the observational data, the indexes selected reflect only some features characterizing the entire task environment. For example the amount of calls exchanged between the sectors concerned by the transition, is an index of the load associated with planning, but the activity of planning to transfer a flow of aircraft is more than just calling adjacent sectors. For example the time necessary to decide which flight level to assign to a sequence of traffic has not been observed. Thus observational data can only partly validate controllers’ assessment of a complex task environment. On the other hand, controllers’ perception of the situation might at times be biased such as when estimating the number of times aircraft were cleared through several flight levels at once.

Self-assessment data and observational data should be considered as complementary rather than competing sources of information. Conclusions about the role of each scenario with respect to the transition task, should reflect an effort to integrate results coming from both self-assessment and observational data.

The different scenarios will be compared through the notion of «usability», i.e., to what extent each scenario can be used to achieve the transition. The comparison will mostly rely on observational data, although the conclusions about the usability of each scenario will be drawn on the basis of the entire body of data collected. Thus statements made by controllers in the questionnaires and during team-debriefing will be integrated to justify the conclusions drawn. An important remark should be made at this point: the exercises concerning transition from RVSM into CVSM (Eastbound traffic) and vice-versa (Westbound traffic). For the last case the constraints were minimal given that aircraft had to be spread over six flight levels right after they established the first radio contact with the Turkish controllers. Controllers had not raised any issues concerning Westbound traffic. Finally the different scenarios proposed affected mostly the traffic going Eastbound. For all these reasons, the analysis of the observational data focuses on the traffic going from RVSM into CVSM.

9.1 INTRODUCING USABILITY

The data recorded during each exercise was used to compare the scenarios along a number of features. These features have been included into the notion of «usability» which is commonly applied when human factors test and evaluation are carried out. «Usability» can be broadly applied as for testing a new procedure (our case), a tool or a new working position. The following definition is adapted to the transition scenarios:

Usability is the extent to which each scenario can be used by air traffic controllers to achieve the transition given a set of tasks and constraints characterizing the operational environment (adapted from INUSE, 1996).
We have already inferred from the answers to the questionnaires and from the team debriefing a number of tasks and constraints characterizing the operational environment. The concept of usability has been broken down into three main ideas:

- **Effectiveness**: How well controllers accomplish the transition using the different scenarios
- **Efficiency**: How costly it is to achieve the transition through each scenario
- **User satisfaction**: How easy it is to learn the new procedure and to what extent controllers feel they master the situation. Sometimes it also included the idea of how pleasant it is to use the new procedure (Mack & Nielsen, 1994).

Thus effectiveness, efficiency and user satisfaction will constitute our criteria for testing usability of RVSM scenario, Route and Buffer zone. The data collected to test the differences among the three scenarios will then be analyzed in terms of the above mentioned criteria, in the order just outlined. The focus of the analysis will be on the two sectors concerned by the transition (E1 and E2) although it will also consider the sectors not concerned by the transition.

### 9.2 EFFECTIVENESS

As already stated, the effectiveness of use implies how well the transition has been accomplished in each scenario. This was measured by verifying:

- a particular aspect of safety
- the effectiveness of the airspace use (see below for details)

A number of indicators have been identified and grouped under the concept of «effectiveness of the airspace use». These indicators are a measure of how «well» the transition has been accomplished with each scenario. Three indicators have been identified:

- Percentage of Requested Flight Level (RFL) reached before leaving the Tehran FIR;
- Range of exit levels;
- Location of the last level change.
9.2.1 Safety violation

A conflict was defined as the violation of the separation minimum 1000 feet and 5 Nm. below FL410 and 2000 feet and 5 Nm. above FL410. As shown in Table 8, there were 6 instances of Loss of separation, none of which occurred in the sectors concerned by transition.

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>TRAFFIC LOAD</th>
<th>SECTOR</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVSM</td>
<td>Medium</td>
<td>SU</td>
<td>2</td>
</tr>
<tr>
<td>RVSM</td>
<td>High</td>
<td>WU</td>
<td>2</td>
</tr>
<tr>
<td>Buffer</td>
<td>High</td>
<td>WU</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 8: Safety violation

9.2.2 Percentages of Requested Flight Levels

The percentage of aircraft being transferred according to their RFL was an indicator of how frequently controllers succeeded in satisfying pilots’ requests. The data from the CVSM scenario has been included to verify whether the transition task decreased the probability of clearing an aircraft to their RFL. Figure 15 shows the percentage of aircraft whose CFL was equal to, lower than and higher than the RFL, for medium traffic load.

Concerning the medium traffic load, CVSM scenario has the higher percentage of aircraft whose CFL was equal to their RFL (figure 15). However the only appreciable difference was between CVSM scenario (about 75% of CFL=RFL) and BUFFER scenario (about 53% of CFL=RFL). RVSM scenario and ROUTE did not significantly differ from each other. This pattern is somewhat reversed in the high traffic load condition where the percentage of CFL=RFL slightly decreases for all of the scenarios but for BUFFER scenario. Scenarios RVSM and ROUTE had the lowest probability of CFL=RFL. The low percentage obtained in ROUTE scenario was also due to an early interruption of the exercises. Had the exercises in the

Figure 15: Percentage of CFL = RFL for medium and low traffic load
ROUTE scenario run further, they would have reached a percentage comparable to those reached in the other scenarios.

When the percentages of CFL=RFL were averaged across conditions (see figure 15) the only appreciable differences were between ROUTE scenario (about 55% of CFL=RFL), BUFFER scenario (about 57% of CFL=RFL) and CVSM scenario (about 70% of CFL=RFL). Overall, there was no appreciable difference between the RVSM, ROUTE and BUFFER scenarios.

To summarize, for the medium traffic load CVSM scenario had the highest percentage of CFL=RFL (75%). This advantage was appreciably reduced when the traffic load was increased. In the high traffic load the probability of CFL=RFL decreased to 60% and the differences between scenarios are less noticeable where CVSM scenario obtained the same percentage as BUFFER scenario (about 60%). Thus traffic load and transition both affect the probability of CFL being equal to RFL. However because the absolute advantages of CVSM disappears in the high traffic load condition, this latter seems to affect more than transition, the probability of CFL=RFL.

### 9.2.3 Range of cleared / exit flight levels

When the simulation stopped some traffic was not close to sector boundaries, thus the actual flight level was not necessarily the exit flight level. For this reason, a distinction was made between cleared and exit flight levels.

Through the questionnaires controllers repeatedly stated that because of the high traffic load, they needed to clear aircraft to flight levels lower than 290. Figures 16 and 17 show the distribution of exit flight levels for the scenarios CVSM, RVSM, Route and Buffer zone for medium and high traffic load.
The three flight levels, i.e., 370, 330 and 290, are the most frequently used in the conditions of medium and high traffic load. A new range of flight levels, from 270 down to 210, appeared in the high traffic load condition. Transition did not seem to be a factor as low flight levels were used even in CVSM scenario.

9.2.4 Position of the last level change

From an operational standpoint, one of the differences between the three scenarios is that no procedure is established for RVSM scenario and controllers are free to effect the transition where they like provided that it is within the Ankara FIR. The question then is whether controllers established a sort of «transition zone» in the sectors where they make the transition and whether that zone changed from one scenario to another as a function of the procedures to be followed.

To mark the «transition zone» for each scenario, a grid was employed to identify the point on a x-y axes where each eastbound aircraft was moved. The transition points, averaged for each scenario, have been plotted to show the observed variability.
On the Y axis of the figure 18, three major landmarks have been identified with respect to the buffer line, i.e., 40 Nm. east and 60 Nm. west of it. The figure intends to show that the range of the transition points varied the most in the ROUTE scenario and the least in the BUFFER scenario. The boundary line in the latter Scenario heavily constrained the degree of freedom concerning the choice of the transition point. On the other hand, the ROUTE scenario showed the greatest variance.

Concerning ROUTE scenario, for medium traffic load condition, aircraft were transitioned on the average at about the same location as for Scenario BUFFER. Aircraft in E2 were transitioned while in the big route structure and in E1 about 120 miles before the beginning of the small route structure. A possible explanation for the early transition in E1 was that before entering the route structure, aircraft had gone through a major intersection point (corresponding to the beacon ERZ) and conflicts over that point were solved at the same time as transition. After checking the «transition point» for each individual aircraft in sector E1 it was found that either aircraft were transitioned while on the route structure or before the beacon ERZ. It was hypothesized that in the later case, transition was effected at the same time as transferring and conflict resolution over the beacon ERZ.

Still concerning ROUTE scenario, in the high traffic load condition, aircraft were transitioned further towards the boundary with Tehran FIR. In E1 that point was about 70 miles before the beginning of the small route structure. A possible explanation for the fact that the «transition point» was closer to the boundary line, in the high traffic load condition, was that controllers did not have the time to solve conflicts over the beacon ERZ and effect the transition simultaneously. That implied that they had to go back to the same aircraft more than once. Later on, data presented in paragraph 9.3.2 confirms the hypothesis that aircraft were moved more than once more often in the high traffic load than in the medium traffic load. That means that the route structure gave controllers the means to postpone transition when necessary and thus allowed for more time to plan their activities.

On-line observations showed that controllers asked pilots if ready to make the transition earlier than requested by the procedure. This was because, in the operational environment, controllers take into account that pilots might not be ready
to change flight levels immediately after receiving the clearance. Thus, the option
of giving pilots some time to respond is a sign of controllers’ comfort.

9.2.5 Summary with respect to position of the last level change

There seemed to be a preference for controllers to solve conflicts and transition at
the same time. In that respect the transition point seemed to be more determined
by the organisation of the airspace and the relative intersection point than by the
established procedures.

For the ROUTE scenario, controllers used the route structure as a resource to
alleviate time pressure. In fact when the traffic load did not allow effecting the
transition at the same time as solving conflicts, controllers postponed the transition
at a later time by using the route structure.

Concerning RVSM and BUFFER scenarios, traffic load did not seem to affect the
choice of the «transition area». The lack of procedure in the RVSM Scenario
allowed for a high variability. On the other hand, controllers respected the
procedure associated with the BUFFER scenario as shown by the low variability in
the choice of the transition area.

9.3 EFFICIENCY

 «Efficiency» means how costly it was for controllers to achieve the transition using
the different scenarios. Before specifying what indicators have been selected for
measuring efficiency, a few assumptions underlying the meaning of «efficiency»
and «cost for controllers» will be highlighted.

First of all, «efficiency» is linked to the notion of resource management and «cost»
to the notion of constraints of the situation. «Resource management» means to
what extent the available resources such as information on flight strips, are, or can
be, used to support the activity. The constraints of the situation result from the
interaction between the task demands, the environmental resources and the
internal resources (such as skills, level of expertise) available to controllers to cope
with the task environment. In other words, if the demands of the situation are high
(i.e., multiple tasks, time pressure), and the resources available (environmental and
internal) are poor, then the situation is constrained. The double arrow in figure 19
means that the task environment and internal resources have a mutual influence on
each other. For example, «Being aware of traffic in adjacent sector» is a task
demand that can be recognized or neglected, depending on how controllers
manage planning and coordination. On the other hand «flow of traffic» (i.e., late
inter-sector transfer) might directly affect subjective workload.
EFFICIENCY: REPRESENTING THE COST OF «TRANSITION»

Task demands
(e.g. Time, pressure, transfer, transition)
Environmental resources
Sectorisation

Internal (cognitive) resources (e.g. planning workload)

Observable performance:
resource management strategies
amount of coordination
management of flight levels changes

CONSTRAINTS OF THE SITUATION

Figure 19: A model for representing the notion of «efficiency»

Second, it is assumed that the constraints of a situation affect the observable performance in terms of how controllers manage the available resources, as shown in the bottom of the figure 19. A number of indicators have been chosen to measure the cost associated with effecting the transition in the different scenarios. Some of these indicators are directly measurable while others have to be inferred from observing controllers and from their self-assessment reports in the questionnaires. These indicators are:

» Management of flight level changes
» Amount of coordination
» Radio & Telephone (R/T) loading
» Need for new planning
» Directly observable workload

Next each indicator will be explained and the data obtained from each of them will be discussed.

9.3.1 Management of flight level changes

Flight level change is one of the tasks defining what transition is about. For example, if an aircraft is flying eastbound at RVSM flight level 350, controllers have the option of climbing the aircraft to flight level 370 or to descend the aircraft to flight level 330. However, if none of these flight levels are available at the time in which the transition is made, then controllers have to either climb the aircraft through several flight levels to reach 410 or to descend it to flight levels 290 or lower. A number of indicators related to the activity of changing flight level have been selected. They are:

» Number and proportion of aircraft moved
9.3.2 Number and proportion of aircraft moved

In this context «moving an aircraft» means to clear the pilot to change flight level. For this simulation, it is assumed that there were three reasons for doing that:

- To solve a conflict
- To effect the transferring
- To make the transition.

First the results concerning the medium traffic load condition will be discussed followed by those for high traffic load condition. The question was whether the need for moving aircraft varied from one scenario to another. CVSM scenario has been included to measure how much more busy the controllers were when the transition was added to their task environment.

The CVSM Scenario had the lowest proportion of aircraft moved (21%), followed by ROUTE scenario (29%). This is not surprising given that CVSM did not imply any transition. The RVSM and BUFFER scenarios had about the same proportion of aircraft moved (45% and 42% respectively). The difference in the proportion of aircraft moved across the «transition» scenarios suggests the two following hypothesis about ROUTE scenario. Either the number of conflicts was lower than in the RVSM and BUFFER scenarios, or that it was sufficient to act on a relatively small subset of aircraft to accomplish at the same time all of the tasks or both. In all cases ROUTE scenario appeared to enhance a more efficient transition with respect to the activity of moving aircraft.
The result that the proportions of aircraft moved were quite close for Scenarios CVSM and Route suggests that CVSM scenario had more conflicts to solve than ROUTE scenario. In other words, in the absence of the transition task, controllers were busy to solve more conflicts in CVSM scenario than in the ROUTE scenario. This hypothesis was confirmed by the fact that the proportion of aircraft moved more than once was quite higher for CVSM scenario than for ROUTE scenario. In fact in the CVSM scenario out of all of the aircraft moved, 19% were moved more than once meaning that moving aircraft once was not enough to accomplish the task. On the other hand, the low percentage of aircraft moved more than once in ROUTE scenario (5%) indicates that one action was enough to accomplish transition and transferring at the same time.

The highest percentage of aircraft moved (45%) and moved more than once (35%) was for RVSM scenario, followed by BUFFER scenario that had about the same percentage of aircraft moved (42%) but a lower percentage of aircraft moved more than once (15%).

To summarize, in the medium traffic load, the percentage of aircraft moved was lowest for CVSM scenario. This is not surprising given that CVSM scenario does not need to make the transition. RVSM scenario had the highest proportion of aircraft moved and moved more than once. In this respect it was the least efficient transition scenario. On the other hand, the proportion of aircraft moved more than once was rather negligible for ROUTE scenario (5%) meaning that this scenario allowed controllers to solve transition and transfer problem simultaneously.

This picture changes in the high traffic load condition. The percentage of aircraft moved and aircraft moved more than once is the highest for ROUTE scenario. As highlighted in paragraph 9.2.3, this implies that in busy condition, controllers did not effect transferring and transition simultaneously but they postponed the latter in the proximity of the smaller route structure. CVSM scenario has the lowest percentage of aircraft moved and moved more than once but this advantage is reduced with respect to the results obtained in the medium traffic load condition. Concerning the BUFFER scenario, although the proportion of aircraft moved is comparable to those obtained for the other transition Scenarios, the proportion of
aircraft moved more than once was the lowest in absolute terms.

To conclude, as far as moving aircraft, increasing the traffic load negatively affects the efficiency of ROUTE scenario. In fact, the percentage of aircraft moved more than once increases sensibly for ROUTE scenario. This confirms the hypothesis presented earlier to explain why in high traffic condition aircraft were transitioned later than in the medium traffic load condition. It was inferred that because controllers were too busy resolving conflicts, they postponed transition at a later time. This is confirmed by the fact that in high traffic load, aircraft are moved more than once much more often than in medium traffic load. On the other hand, neither RVSM scenario nor Buffer seems to be affected by the increase of traffic load.

9.3.3 Number and proportion of levels cleared at once and of «standby» levels.

Throughout the questionnaire controllers stated that in heavy traffic condition they had to clear aircraft to low flight levels and that the same aircraft had to go through many flight levels at once. The first statement has already been verified (paragraph 9.2.3). Concerning the number of levels cleared at once, it was checked how often aircraft were cleared one, two, three, four and five levels respectively. «flight level changes» were defined as following:

1 flight level change = 2000 feet  
2 flight level change = 4000 feet  
3 flight level change = 6000 feet  
4 flight level change = 8000 feet  
5 flight level change = 10,000 feet

![Figure 22: Number of Flight Levels(FL) cleared at once: Medium traffic load](image)

Across all conditions and all scenarios, 15% out of all of the aircraft moved more than once (52 aircraft out of 341), were cleared through 3 to 5 flight levels at once. Eighty-eight percent of these aircraft belonged to the heavy traffic condition. The highest proportion (28 out of 52, i.e., 54%) was for aircraft being cleared through 3 flight levels in the heavy traffic condition. In this case efficiency did not seem to be affected by scenario but only by the traffic load condition.
We shall notice that flight level changes do not all have equal status in CVSM and RVSM situation. In fact, for CVSM 2 and 4 flight level changes will leave aircraft on allowed flight levels. For example an aircraft flying eastbound at flight level 370 could be cleared to FL 410 thus going through 2 flight levels at once. Or else, the aircraft could be cleared to FL 290, thus going through 4 flight levels at once. All of these levels are Eastbound CVSM flight levels. However for tactic reasons, controllers might temporarily clear aircraft to opposite direction flight levels. If an aircraft flying eastbound at CVSM flight level 370 is cleared to FL 390 it will go through 1 flight level; or if it is cleared to FL 310 it will go through 3 flight levels at once. In both cases the aircraft has been cleared to westbound CVSM flight levels and thus controllers need to go back to this aircraft to clear it to the appropriate flight eastbound CVSM flight levels. For this reason, 1 and 3 flight level changes are said to be stand by, while 2 and 4 flight level changes are called permanent levels.

Inversely, concerning aircraft that need to be transitioned from eastbound RVSM to CVSM, flight level changes 2 and 4 are considered stand by while flight level changes 1, 3 & 5 are considered permanent. The table below summarizes the stand by levels and the permanent levels for CVSM and RVSM respectively.

<table>
<thead>
<tr>
<th></th>
<th>Stand by level changes</th>
<th>Permanent level change</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVSM</td>
<td>1, 3, 5</td>
<td>2, 4</td>
</tr>
<tr>
<td>RVSM</td>
<td>2, 4</td>
<td>1, 3, 5</td>
</tr>
</tbody>
</table>

Table 9: Number of flight levels aircraft go through at once

In the CVSM environment, when an aircraft is cleared through 2 flight level changes, that implies monitoring for crossing one flight level occupied by traffic coming from opposite direction. When the aircraft is cleared through 4 flight level changes the monitoring demands increase as it goes through two flight levels occupied by traffic coming from opposite direction. Similarly for RVSM, the more flight levels aircraft are cleared through at once, the higher the monitoring demands. It follows that going through 2 flight level changes for CVSM and 1 flight level change for RVSM is the more economic and safest way of changing flight levels. Those were called the «easiest» option.

For medium traffic load, ROUTE scenario was the most efficient of all as it allowed for the highest frequency of the «easiest option» i.e., 1 flight level change (85%). Notice that CVSM Scenario was not better than any other transition Scenario, thus adding transition did not necessarily imply making flight level changes more demanding for controllers.

Concerning the frequency of «stand by levels», ROUTE scenario had the lowest percentage (15%) followed by CVSM scenario, RVSM and Buffer zone (23%). Thus there was a tendency for ROUTE scenario to be a little less demanding than CVSM scenario in spite of the fact that transitioning could create new conflicts.

To summarize, for medium traffic level, ROUTE scenario appeared to be the most efficient inasmuch as it allowed for the highest frequency of the easiest option (1 flight level changes) and the lowest percentage of use of «standby level».

In the high traffic load condition, the percentage of the easiest option decreased for all of the Scenarios and the BUFFER zone scenario got the lowest percentage of all
(47%). CVSM scenario had a slight advantage over Scenarios RVSM and Route (65% vs. 58%) (see figure 23).

![Figure 23: Number of Flight Levels (FL) cleared at once High traffic load](image)

Concerning the use of «stand by» levels, BUFFER scenario had the highest frequency (40%) while the CVSM and RVSM Scenarios had the lowest (23%) and ROUTE scenario was somewhat in between (28%)

To summarize, for high traffic load, the task environment became more demanding for all of the scenarios but the least efficient was the BUFFER scenario as it had the lowest frequency of use of the easiest option and the highest proportion of the «stand-by» levels. With this respect, the difference between RVSM scenario and Buffer zone, seems to suggest that the presence of the boundary line implies a more frequent use of the «stand-by» levels may be because controllers have less time to solve the conflict before making the transition.

To conclude, while traffic load seemed to affect the efficiency of all of the scenarios, BUFFER scenario was the least efficient in terms of frequency of use of the easiest option and of the «stand-by» levels.
9.3.4 Amount of co-ordination and R/T loading

The following three measurements were carried out to assess the amount of coordination in the different scenarios,

1. The number of telephone calls made in each scenario, was counted.
2. The number of telephone calls E1 and E2 made to any other sector. The focus was on E1 and E2 as they were concerned by the transition.
3. The number of telephone calls that were made just between E1 and E2.

Thus the amount of coordination between E1 and E2 was an indicator of how costly it was to effect the transition in the different scenarios. The automatically recorded data might not represent all of the inter-sector communications as at times controllers from different positions might have been talking to each other without using the telephone.

The ROUTE Scenario had the lowest number of telephone calls followed by the BUFFER scenario. The higher number of telephone calls in the RVSM scenario indicated that controllers were quite busy with co-ordination with respect to the other two Scenarios (see table 10).

<table>
<thead>
<tr>
<th></th>
<th>RVSM SCENARIO</th>
<th>ROUTE SCENARIO</th>
<th>BUFFER SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Total number of communications (over 6 exercises)</td>
<td>324</td>
<td>221</td>
<td>230</td>
</tr>
<tr>
<td>2- Total number of communications for (E1+E2) to other sectors</td>
<td>65</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Ratio Line 2/1</td>
<td>20%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>3- Total number of communications between E1 and E2 only</td>
<td>22</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Ratio line 3/2</td>
<td>33%</td>
<td>26%</td>
<td>38%</td>
</tr>
</tbody>
</table>

Table 10: Number of telephone calls for Scenarios RVSM, Route & Buffer

The proportion of telephone calls made by E1 and E2 to any other sector was highest for the BUFFER scenario, which was then the most penalizing. RVSM and Route did not differ between each other. This is a bit surprising given that the new route structure introduced in the Scenario Route should decrease the need for coordination. May be that in heavy traffic condition the benefits of the one-way structure were suppressed.

When considering only the telephone calls exchanged between E1 and E2, then the benefits of the ROUTE scenario appeared evident. The percentage of calls between the two transition sectors was the lowest for the ROUTE scenario and the highest for the BUFFER zone scenario.
To summarize, the BUFFER scenario was the more costly in terms of need for coordination. Coordination between E1 and E2 was the lowest in the ROUTE scenario and thus in this respect it was the most efficient.

9.3.5 Need for new planning

Concerning the need for new planning, controllers often remarked that due to sectorisation and to high flight strips output, they often needed to make a new plan of the exiting traffic. Or, controllers would postpone as late as possible the decision of what flight level aircraft should be cleared to, in order to avoid re-planning.

Planning or late planning might not be directly observable as controllers might make a decision without any observable action. In order to get some observable evidence supporting what controllers stated, it was checked whether controllers would write more than one Exit Flight Level (XFL) on the strip. Whenever it was found that a strip contained two or more XFLs deleted, it was inferred that controllers needed to change their previous planning. Strips from the RVSM, ROUTE and BUFFER scenarios were checked, in the medium and high traffic load condition.

For the medium traffic load condition, a part from the BUFFER scenario, the need for replanning followed the same pattern in E1 and E2. There was a slight increase for sector E2. The CVSM Scenario had the lowest percentage of flight strips with two or more XFLs. The highest need for replanning was found for the BUFFER scenario in sector E1.
For high traffic load, the need for replanning decreases for E1, with respect to medium traffic load, and it remains approximately the same for E2. The ROUTE scenario seems particularly penalized in sector E2 may be due to the traffic load, judged at times unrealistic. The decrease in replanning observed when comparing E1-medium traffic load and E1-high traffic load, might be due to the fact that during high traffic load, E2 did not make any requests for the transferring traffic coming from E1. If that were true, the fairly stable percentage of flight strips with two or more XFLs in sector E2 shows that both in medium and high traffic load, the need for replanning are quite consistent.

9.4 USER SATISFACTION

The notion of user satisfaction has been previously defined as including:

- Easy of learning the new procedure
- Feeling of mastering the situation
- Pleasure in using the new procedure.

Concerning the first item, evidence was obtained from an informal questionnaire that both learning material (contained in the Controllers Handbook) and the training exercise were «good». Thus from a learning perspective, controllers were satisfied.

Concerning the second item, feeling of mastering the situation, controllers' self-assessment data on workload and R/T load were used to infer the degree to which they felt they mastered the situation. Both indexes refer to how busy controllers felt they were in the different Scenarios. The underlying assumption is that the busier controllers felt they were, the higher the time pressure and the lower the degree of freedom they felt they had. Few degrees of freedom translate into a feeling of not quite mastering the situation.

Finally the Questionnaire about RVSM, ROUTE & BUFFER zone scenarios included a question about satisfaction. That question addresses the issue of pleasure involved in working in each transition Scenario. Next the data concerning the degree of mastering the situation and then the data about «pleasure of use» are going to be presented.
9.5 CONTROLLERS SELF-ASSESSMENT DATA: POST-EXERCISE QUESTIONNAIRES

Controllers assessed their workload in two different circumstances and if different answers were obtained, it meant that the «thing» they were evaluating in the two circumstances was different. In the first case, the self-assessment was produced at the end of each exercise («post-exercise» questionnaires) and in the second it was done while answering a questionnaire about each scenario. Thus in the first circumstance the scores collected have been averaged over all exercises in each Scenario. The second circumstance implies a one-time overall assessment.

While rating workload at the end of each exercise, controllers did not appear to be affected by the transition. Combining E1 & E2, for medium traffic load, the ROUTE scenario got the lowest average score (x=4.12) while RVSM the highest (x=6) meaning that effecting the transition without any help is more costly than when assisted either by a procedure or by a new route organisation.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Workload</th>
<th>RT-load</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVSM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>7.67</td>
<td>6.33</td>
</tr>
<tr>
<td>E2</td>
<td>3.67</td>
<td>4.17</td>
</tr>
<tr>
<td>WU &amp; SU</td>
<td>4.22</td>
<td>4.11</td>
</tr>
<tr>
<td>RVSM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>7.33</td>
<td>6.50</td>
</tr>
<tr>
<td>E2</td>
<td>4.67</td>
<td>4.67</td>
</tr>
<tr>
<td>WU &amp; SU</td>
<td>4.00</td>
<td>3.89</td>
</tr>
<tr>
<td>Route</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>5.50</td>
<td>4.67</td>
</tr>
<tr>
<td>E2</td>
<td>4.33</td>
<td>4.33</td>
</tr>
<tr>
<td>WU &amp; SU</td>
<td>3.88</td>
<td>3.38</td>
</tr>
<tr>
<td>Buffer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>6.67</td>
<td>6.00</td>
</tr>
<tr>
<td>E2</td>
<td>3.00</td>
<td>4.67</td>
</tr>
<tr>
<td>WU &amp; SU</td>
<td>3.89</td>
<td>3.33</td>
</tr>
</tbody>
</table>

Table 11: Average scores for workload and RT/load for CVSM, RVSM, Route & BUFFER scenarios for medium traffic load (on a 1 to 10 scale)

As the traffic load increased, the slight advantage of the ROUTE scenario over the BUFFER scenario disappears, and their average score was lower than the RVSM and CVSM Scenarios.

For medium traffic load, when comparing E1 vs. E2 a consistent pattern was observed for the CVSM, RVSM, Route & BUFFER scenarios: Workload was always rated lower for sector E2. However as traffic load increased the tendency reversed for all of the Scenarios but for the Buffer: Workload in E2 was rated higher than in E1.

Combining the average scores for E1 for medium and high traffic load and comparing them with those obtained from E2, it was found that the lowest workload score was affected to E2 in the BUFFER zone scenario (x=2.9) followed by E2 in the ROUTE scenario (x=4.83). This results in quite opposite from the satisfaction scores in the «Scenario Questionnaire», where the sector E2 from the BUFFER scenario got the lowest «satisfaction» score.
Comparing workload expressed in the «Scenario Questionnaire», it was found that controllers tended to rate their workload higher than when doing it in the «post-exercise» questionnaires. In the latter case, gaining familiarity could have contributed to lower workload, while rating the scenarios once and for all induced controllers to judge their workload higher.

To conclude, the difference shown by controllers when assessing workload in the post-exercise and in the scenario questionnaire might reflect the fact that in the latter circumstance, controllers have indeed expressed their overall judgement over all of the scenarios. In other words, it might indicate that their overall perception of the different scenarios was more influenced by the traffic load than by the different solutions proposed.

At the end of each exercise, controllers were asked to assess their R/T loading. Their scores increased for high traffic load, but the RVSM scenario did not receive the highest score as expected, given that it had the highest number of telephone calls exchanged.

The third criterion to measure users satisfaction was how pleasant it is to use, each scenario to effect transition. In the «Scenario questionnaires» that issue was addressed by a question on «satisfaction». Controllers rating showed a high degree of satisfaction while working with RVSM in those sectors not concerned by the transition. On the other hand, controllers were quite unsatisfied when working in E2 in the BUFFER scenario. Overall, controllers preferred working in E1 sector except in the ROUTE scenario where they did not have any preference. This was confirmed by the «post-exercise» questionnaires for medium traffic load. This was understandable given that the problem of the late inter-sector transferring affected E2 in the RVSM and BUFFER scenario but not in the ROUTE scenario. However as it has been noted, controllers’ dissatisfaction with sector E2 in the BUFFER scenario is not consistent with the lowest workload rating that sector got in the «post-exercise questionnaire»

<table>
<thead>
<tr>
<th>Average</th>
<th>Sector</th>
<th>Workload</th>
<th>RT-load</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVSM</td>
<td>E1</td>
<td>6.83</td>
<td>6.67</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>8.00</td>
<td>7.17</td>
</tr>
<tr>
<td></td>
<td>WU &amp; SU</td>
<td>5.78</td>
<td>5.00</td>
</tr>
<tr>
<td>RVSM</td>
<td>E1</td>
<td>6.83</td>
<td>6.17</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>8.17</td>
<td>7.33</td>
</tr>
<tr>
<td></td>
<td>WU &amp; SU</td>
<td>4.88</td>
<td>4.00</td>
</tr>
<tr>
<td>Route</td>
<td>E1</td>
<td>4.00</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>5.33</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>WU &amp; SU</td>
<td>3.33</td>
<td>5.60</td>
</tr>
<tr>
<td>Buffer</td>
<td>E1</td>
<td>6.50</td>
<td>5.83</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>2.83</td>
<td>6.80</td>
</tr>
<tr>
<td></td>
<td>WU &amp; SU</td>
<td>4.78</td>
<td>4.33</td>
</tr>
</tbody>
</table>

Table 12: Average scores for workload and RT/load for CVSM, RVSM, ROUTE & BUFFER scenarios for high traffic load (on a 1 to 10 scale)
To conclude, controllers’ self-assessment data showed that the, ROUTE and BUFFER Scenarios were both preferred to the RVSM and CVSM Scenario in both traffic load conditions with a preference for the ROUTE obtained for medium traffic load, where both workload and R/T Load are rated the lowest. As the traffic load increased there was no clear preference expressed.
10. CONCLUSIONS

With reference to the specific objectives the following conclusions were reached from the simulation.

Investigate ATC techniques for handling traffic making the transition from an RVSM environment to a non-RVSM procedural environment and vice-versa.

It can be concluded that transition was achieved in all of the Scenarios, that is, aircraft were always established at their CVSM flight levels before entering the Tehran FIR. This was true for all exercises.

The controllers felt that their workload in the sectors not affected by transition, was lower when using RVSM. In the transition sectors, the workload was similar to CVSM as they had to do the additional tasks of transition and transfer to Tehran FIR. There was no significant difference between the workload in the three RVSM scenarios.

Generally speaking, the controllers felt that any new concept for improving air traffic management in the transition area should not disregard the problem of transferring traffic to a non-radar airspace.

There were a number of features constantly raised while evaluating each scenario. These features related to:

- The operational/simulated environment:
  - The 10-minute separation rule for transferring traffic to Tehran,
  - Sector boundary
  - Flight strip output
  - Traffic load

- Activity related features:
  - Planning
  - Co-ordination

These elements constitute the “evaluation context” within which these Scenarios have been judged by controllers. Further, performance in these Scenarios has to be assessed within this evaluation context. In fact it was found that features of the operational and simulated environment differently affected controllers’ judgement and performance in the different Scenarios.

Measurement of controllers’ preferences did not produce consistent results throughout the different testing conditions:

- While answering the questionnaires about the different transition scenarios, their preferences went clearly to the ROUTE Scenario followed by RVSM.
- Objective performance was measured in terms of management of flight level changes and R/T load. In the first case the ROUTE Scenario was better than the RVSM and Buffer Scenarios only in the medium traffic load condition. As traffic load increased there was no Scenario significantly better than another.
Self-assessment data did not produce fully consistent results. While evaluating workload after each exercise, controllers equally preferred the BUFFER and the ROUTE Scenarios. On the other hand, the BUFFER Scenario got the lowest “satisfaction” score and workload was assessed quite high in all of the Scenarios while answering the scenario questionnaires. While tentative explanations for this are provided in the Report, these results should be interpreted with caution.

The table below summarizes the reasons for judging RVSM and BUFFER Scenarios more demanding than the ROUTE Scenario:

<table>
<thead>
<tr>
<th>RVSM &amp; BUFFER Scenarios</th>
<th>ROUTE Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Time Pressure</td>
<td>• Easier to make transfer/transition</td>
</tr>
<tr>
<td>• Late inter-sector transferring</td>
<td>• Higher user satisfaction</td>
</tr>
<tr>
<td>• Monitoring demands</td>
<td>• More error tolerant</td>
</tr>
<tr>
<td>• Reduced control option</td>
<td>• Less than optimal resource management strategies acceptable</td>
</tr>
<tr>
<td>• Awareness of traffic of adjacent sectors</td>
<td></td>
</tr>
</tbody>
</table>

Notice that the costs and benefits of each Scenario are stated from the standpoint of the controllers’ activity. In fact, resources needed to implement the ROUTE organization might be higher than those needed to implement the BUFFER zone.

Examine the following airspace structure issues

- **testing a revised route structure to handle transition**

The major issues concerning the transition sectors in the ROUTE scenario were:

- It eliminated a route between the two sectors concerned by the transition. This resolved the late inter-sector transfer problem
- It do not need additional co-ordination on its own
- The establishment of two one-way routes eliminated the possibility of face-to-face conflicts in the transition sectors
- Radar vectoring was not necessary in the transition sectors
- Monitoring demands were reduced with respect to the other two scenarios
- Transition and transfer were eased because of the unidirectional routes

A clear preference was expressed for the ROUTE scenario for the above reasons.
• **Assess the impact of a defined Buffer Zone for handling transition**

The limits imposed by the boundary line in the BUFFER Scenario were respected in all of the traffic load conditions.

All of the elements included in the evaluation context affected the handling of the transition in the BUFFER Scenario.

In particular this scenario requires specific attention to be paid to:

Airway structure  
Sector configuration

• **Assess the impact of RVSM on sectorisation.**

The airway structure and the sectorisation chosen made the BUFFER Scenario less desirable than the ROUTE Scenario.

**Further validate the RVSM ATC Procedures developed by the ATM Procedures Development Sub Group (APDSG) of the ANT.** This will include:

• **RT Phraseology.**

The RT phraseology and the information displayed on the flight strips were considered appropriate by all the controllers. Some confusion did occur between the display of non-RVSM and non-RVSM State aircraft due to the fact that the Radar Position Symbol was the same for both aircraft and identification rested upon the pilot or the planning controller to notify the executive controller.

• **RVSM procedures - including the handling of non-RVSM approved traffic entering RVSM airspace which are required to descend below FL290 (or climb above FL410), and non-RVSM approved State aircraft which have to be incorporated in the RVSM area.**

All of the controllers felt that the non-RVSM traffic did increase their workload, however, no major problems were experienced with descending the non-RVSM (non-State) traffic below FL290. The controllers also managed to climb non-RVSM traffic (which was below FL290 and exiting RVSM airspace to CVSM airspace) to their RFL whilst still within the transition area.
11. RECOMMENDATIONS

When considering the airspace to be used for transition the simulation has shown that careful evaluation is required in respect to the operational environment and the main controller tasks.

It is recommended that the main aspects to be taken into account are as follows;

- Route Structure
- Co-ordination requirements
- Adjacent airspace
- ATC procedures (Letters of Agreement)
- Traffic load

The Buffer zone is likely to be a solution applicable to a wider range of airway organizations with respect to the Route structure. While the Route structure is less demanding from a cognitive resource standpoint, the Buffer Zone is less demanding from an environmental standpoint.

When implementing a Buffer zone, the study highlighted the following issue:

- The boundary line should not intersect major crossing points.
Traduction en langue française du Résumé, de l'Introduction, des Objectifs, des Conclusions et Recommandations

RÉSUMÉ

Le concept approuvé par l’ OACI de réduction de la séparation verticale minimum (RVSM : Reduced Vertical Separation Minimum) a pour objectif de réduire la séparation verticale des aéronefs de 2000 à 1000 pieds, entre les niveaux de vol 290 et 410 inclus. La mise en place des séparations RVSM dans l’espace aérien Européen (EUR RVSM) aura lieu le 24 Janvier 2002.

La simulation RVSM4 (quatrième simulation temps réel sponsorisée par Eurocontrol) a eu pour objectif l’étude des effets de la transition entre un espace aérien RVSM et un espace CVSM (Conventional Vertical Separation Minimum - 2000ft).

L’espace aérien choisi pour l’expérimentation a été la FIR d’Ankara (Turquie) car elle a en charge le transfert du trafic vers la FIR de Téhéran qui est un environnement non-radar, et qui devrait rester CVSM après que le concept RVSM Européen soit mis en application.

Des contrôleurs du CCR d’Ankara ont participé à trois semaines de simulation qui se sont déroulées à l’ENAC (Ecole Nationale Française de l’Aviation Civile) à Toulouse, dans le cadre d’un partenariat de simulation avec Eurocontrol. Les trois échantillons de trafic utilisés ont été construits à partir d’enregistrements de trafic réel de 1998, augmentés de 40% afin de simuler les niveaux de trafic prévus en 2002.

Les différents scenarii utilisés pour l’expérimentation ont été:

Scénario 1 : CVSM (scénario de référence)
Scénario 2 : RVSM (première utilisation des six niveaux de vol supplémentaires par les Contrôleurs, sans procédure fournie pour effectuer la transition)
Scénario 3 : ROUTE (RVSM utilisant un système de routes modifié pour effectuer la transition)
Scénario 4 : BUFFER (RVSM utilisant une zone définie, appelée “Buffer Zone” pour faciliter la transition.)

Les scénarii 2, 3 et 4 ont été testés afin de déterminer dans quelle mesure chaque scénario aidait les contrôleurs à gérer la transition.
Les résultats ont montré que la transition était possible dans chaque scénario. D’autre part, ils ont mis en évidence le fait que la transition ne peut être étudiée hors du contexte dans lequel elle est effectuée, et qu’il s’agit donc de prendre en compte un environnement opérationnel global. Les principaux éléments identifiés comme affectant la gestion de la transition sont : la sectorisation, le système de routes, les ressources nécessaires, l’utilisabilité, les besoins de coordination et les transferts d’un environnement radar vers un environnement non-radar.
Les contrôleurs Turcs ont montré une préférence pour le système de routes modifié.
Les données objectives ont montré que :
la performance (mesurée par la gestion des changements de niveaux de vol) dans le scénario ROUTE n’était pas pénalisée par la tâche de transition ;
les besoins en coordination était plus faibles dans le système ROUTE que dans les autres scénarii.
Les données sur la charge de travail des contrôleurs doivent quant à elles être interprétées avec précaution. Certaines données semblent mettre en évidence que la charge de travail ressentie par des contrôleurs travaillant dans les secteurs non concernés par la transition était plus faible dans les scénarios RVSM. D’autres données ont montré que la charge de travail était un peu plus faible pour les scénarii BUFFER et ROUTE que pour le scénario CVSM, indiquant alors que la transition n’était pas perçue comme une charge de travail supplémentaire.

1. INTRODUCTION

RVSM

La réduction de la séparation verticale minimum (RVSM) est un concept approuvé par l’OACI (Organisation de l’Aviation Civile Internationale) qui a pour objectif la réduction de la séparation verticale des aéronefs de 2000 à 1000 pieds entre les niveaux de vol 290 et 410 inclus.

TRANSITION RVSM

Bien que la zone de mise en œuvre de RVSM ne soit pas encore déterminée, la Turquie se devrait situer à sa limite. La DHMI (Turkish Aviation Administration - Administration de l’Aviation Turque) a accepté de mettre à disposition des équipes d’experts et de contrôleurs afin d’effectuer une simulation ayant pour but d’étudier les effets de la transition. Le choix de la Turquie a été particulièrement appréciable puisque les ATS (Air Traffic Services - Services du Trafic Aérien) de la FIR adjacente à l’Est travaillent uniquement aux procédures. Les objectifs de la simulation ont été ainsi pu être centrés sur les problèmes relatifs à la transition d’un environnement CVSM non-radar et vers un environnement RVSM et vice versa. La FIR d’Ankara est divisée en quatre secteurs; les secteurs E1 et E2 effectuant la tâche de transition vers l’est de la FIR et à l’intérieur de l’espace aérien Turc.
2. OBJECTIFS

OBJECTIFS GENERAUX

Evaluation de l’impact de la Transition entre RVSM et CVSM sur la structure de l’espace aérien (sectorisation comprise), et les procédures et techniques ATC dans l’espace aérien Turc (Ankara).

OBJECTIFS SPECIFIQUES

1. Etude des techniques ATC (Air Traffic Control) pour la gestion de la transition d’un espace RVSM vers un espace CVSM aux procédures et vice-versa.

2. Etude des configurations d’espace aérien suivantes :
   - Evaluation d’un système de routes modifié permettant la gestion de la transition
   - Evaluation de l’impact d’une Buffer Zone sur la gestion de la transition
   - Evaluation de l’impact de l’application de RVSM sur la sectorisation.

3. Validation des procédures ATC RVSM développées par le sous groupe APDSG (ATM Procedures Development Sub Group) de l’ANT (ANT = Airspace and Navigation Team). Cette évaluation s’intéressera :
   - A la phraséologie RT (Radio & Téléphone)
   - Aux procédures RVSM - comprenant la gestion des trafics non approuvés RVSM pénétrant l’espace aérien RVSM qui doivent alors être clairés au-dessous du niveau 290 (ou au dessus du niveau 410), et des aéronefs d’État non approuvés RVSM devant être intégrés dans la zone RVSM.
3. CONCLUSIONS

En référence aux objectifs spécifiques, la simulation a permis d’établir les conclusions suivantes.

Etude des techniques ATC (Air Traffic Control) de gestion du trafic aérien pour effectuer la transition entre des environnements RVSM et CVSM et vice-versa.

La transition a pu être effectuée dans tous les scénarii, c’est-à-dire que les aéronefs ont toujours été livrés à un niveau de vol CVSM avant leur entrée dans la FIR de Téhéran, et ce, pour tous les exercices.

Les contrôleurs ont évalué leur charge de travail sur les secteurs non concernés par la transition comme moins élevée en utilisant la RVSM. En ce qui concerne les secteurs devant effectuer la transition, la charge de travail était similaire à celle de la CVSM alors qu’ils avaient à accomplir les tâches additionnelles dues à la transition et au transfert vers la FIR de Téhéran. Il n’y a pas de différences significatives entre les charges de travail des trois scénarii RVSM.

De manière générale, les contrôleurs ont considéré qu’aucun nouveau concept destiné à améliorer la gestion du trafic aérien ne permettait d’occulter le problème de transfert du trafic vers un espace non-radar.

Certaines caractéristiques ont constamment été relevées dans l’évaluation de chaque scénario. Ces caractéristique se rapportaient à :

- L’environnement opérationnel/simulé :
- La règle des 10 minutes de séparation pour le transfert de trafic vers Téhéran,
- Les limites de secteurs
- La sortie des strips
- La charge de trafic

Les caractéristiques liées à l’activité :

- Le planning
- La coordination

Ces éléments constituent le "contexte d’évaluation" à partir desquels les scénarii ont été jugés par les contrôleurs. La performance de ces scénarii ne doit être évaluée que dans ce contexte. En effet, certaines caractéristiques des environnements opérationnels et simulés peuvent influencer différemment le jugement et le travail des contrôleurs dans les différents scénarii.

L’évaluation des préférences des contrôleurs dans les différentes conditions d’expérimentation n’a pas donné de résultats significatifs.

- Les réponses aux questionnaires sur les différents scénarii de transition, montrent une préférence nette pour le scénario ROUTE, suivi du scénario RVSM.
- La performance a été mesurée à l’aide des paramètres objectifs que sont la gestion des changements de niveaux de vol et la charge de communication radio & téléphone. En ce qui concerne la gestion des niveaux de vol, le scénario
Route présente de meilleurs résultats que les scénario RVSM et BUFFER, mais seulement pour une charge de trafic moyenne. Pour une charge de trafic élevée, aucun scénarios ne donne de meilleurs résultats que les autres.

- Les auto évaluations n’ont pas permis de dégager de résultats probants. Lorsque la charge de travail est évaluée après chaque exercice, les résultats montrent un même niveau de préférence pour les scénarios ROUTE et BUFFER. En revanche, le scénario BUFFER obtient le plus bas score de satisfaction, et la charge de travail est évaluée comme relativement élevée dans tous les scénarios en réponse aux "Scenario Questionnaires". Bien que le rapport présente des tentatives d’explication, ces résultats doivent être interprétés avec précaution.

Le tableau ci-dessous résume sommairement les raisons pour lesquelles les scénarios RVSM et ROUTE ont été jugés plus contraignants que le scénario ROUTE.

<table>
<thead>
<tr>
<th>Scénarios RVSM &amp; TRANSITION</th>
<th>Scénario ROUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pression temporelle</td>
<td>Transferts/Transition plus facile</td>
</tr>
<tr>
<td>Transferts inter-secteurs tardifs</td>
<td>Satisfaction de l’utilisateur plus élevée</td>
</tr>
<tr>
<td>Surveillance radar astreignante</td>
<td>Plus grande tolérance à l’erreur</td>
</tr>
<tr>
<td>Alternatives de contrôle restreintes</td>
<td>En deçà du seuil optimal des méthodes de gestion concevables</td>
</tr>
<tr>
<td>Dépendance au trafic des secteurs adjacents</td>
<td></td>
</tr>
</tbody>
</table>

Remarque : les avantages et inconvénients de chaque scénario sont établis sur la base du travail des contrôleurs. En fait, les ressources requises pour mettre en application l’organisation ROUTE pourraient être plus élevées que celles de la zone BUFFER.

**Evaluation les différentes configuration de l’espace aérien**

- **Expérimentation d’un système de routes modifié afin de gérer la transition**

Les principaux résultats concernant les secteurs de transition dans le scénario ROUTE ont été :

- L’élimination d’une route entre les deux secteurs devant effectuer par la transition a résolu le problème de transfert tardif inter-secteurs.
- Ce nouveau système de route ne nécessite pas de coordinations supplémentaires
- Les deux routes à sens unique permettent d’éliminer le risque de conflits face-à-face dans les secteurs de transition.
- Le guidage radar n’a pas été nécessaire dans les secteurs de transition.
- Les exigences de surveillance radar ont été réduites en comparaison avec les deux autres scénarii.
- Les routes unidirectionnelles ont facilité la transition et le transfert.

Les points suivant expliquent la préférence évidente exprimée pour le scénario ROUTE.

- **Evaluation de l’impact de la BUFFER zone sur la gestion de la transition**
Les limites de la BUFFER zone ont bien été respectées quelques soient les charges de trafic simulées.
Tous les éléments décrits dans le contexte d’évaluation ont influé sur la gestion de la transition dans le scénario BUFFER.
Ce scénario requiert une attention particulière en ce qui concerne les problèmes de:

Système de routes
Sectorisation
• Evaluation de l’impact de la RVSM sur la sectorisation.

Le système de routes et la sectorisation simulés induisent une préférence envers le scénario ROUTE plutôt que envers le scénario BUFFER.

Validation des procédures RVSM ATC développées par le sous groupe APDSG (ATM Procedures Development Sub Group) de l’ANT.(Airspace and Navigation Team) comprenant :

• La phraséologie RT (Radio & Téléphone).

La phraséologie RT et les informations délivrées sur les strips ont été jugées convenables par tous les contrôleurs. Une certaine confusion a pu être relevée entre l’affichage radar des aéronefs non-RVSM et celui des aéronefs non-RVSM d’Etat. Cette confusion était dûe au fait que la position du symbole radar était la même pour les deux types d’aéronefs, leur identification reposant sur le pilote ou le contrôleur organique qui devaient informer ensuite le contrôleur radar.

• Les procédures RVSM - comprenant la gestion des trafics non approuvés RVSM pénétrant l’espace aérien RVSM et requis au-dessous du niveau 290 (ou au-dessus du niveau 410), et des aéronefs d’Etat non approuvés RVSM devant être intégrés dans la zone RVSM.

La gestion du trafic non approuvé RVSM : tous les contrôleurs ont estimé que le trafic non-RVSM augmentait leur charge de travail. Cependant, il n’y a eu aucun problème majeur dû à la gestion du trafic non-RVSM (non d’Etat) qui devait être descendu en dessous du niveau 290. Les contrôleurs géraient également la montée du trafic non-RVSM (qui était en-dessous du niveau 290 et quittait l’espace aérien RVSM pour l’espace aérien CVSM) vers leur RFL (Request Flight Level - niveau plan de vol) alors qu’il était encore dans la zone de transition.
3. RECOMMANDATIONS

Lors de l’étude de l’espace aérien requis pour effectuer la transition, la simulation a montré qu’une attention particulière doit être portée à l’environnement opérationnel et aux tâches principales de contrôle.

Il est recommandé de prendre en compte les principaux aspects suivant :

- Organisation des routes
- Besoins de coordination
- Espace aérien adjacent
- Procédures ATC (Lettres d’accord)
- Charge de trafic

La BUFFER zone semble être une solution applicable à une échelle plus étendue d’organisations de routes aériennes que l’organisation ROUTE. Alors que l’organisation ROUTE est moins exigeante du point de vue des ressources cognitives, la BUFFER Zone est moins exigeante du point de vue de l’environnement.

Pour l’application d’une BUFFER Zone, l’étude a souligné le point suivant :

- La limite de la BUFFER zone ne doit pas passer au dessus des principaux points de croisement.
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Annex A: MAPS
Annex B: CONTROL ROOM LAYOUT
Annex C: SIMULATION PARTICIPANTS
RVSM4 PARTICIPANTS

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