Point Merge System

Results of ENAV Prototyping Sessions
Abstract

This document contains the results of the first phase of the ENAV Point Merge System (PMS) project, aimed to assess the domain suitability and controllers' initial acceptability of applying the PMS concept in Rome Terminal Area (TMA).

It presents the results of four prototyping sessions held at Rome Area Control Centre (ACC) in March, April, May and June 2008. During these prototyping sessions the PMS concept has been introduced in Rome TMA for the management of traffic to Fiumicino airport (LIRF), with runways configurations 16R/L and 34L/R and in both full runways configurations and single runway operations. The introduction of the PMS concept did not affect the traffic to Ciampino airport (LIRA) – also included in Rome TMA – that continued to be managed in conventional way.

All the studies produced positive results on the user acceptability and domain suitability of introducing the point merge method in Rome TMA. They also confirmed the validity of the incremental and iterative validation approach adopted. A large set of recommendations has been produced that are expected to reveal useful in both the preparation and conduct of the following real time simulation, as well as for the application of the method in operation. Lesson learnt in the project are included in the conclusions.
# AUTHORS AND REVIEW PROCESS

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## DOCUMENT APPROVAL

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# DOCUMENT CHANGES RECORD

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## Acronyms and Abbreviations

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<th>Abbreviation</th>
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<td>Area Control Centre</td>
</tr>
<tr>
<td>AMAN</td>
<td>Arrival Manager</td>
</tr>
<tr>
<td>CDA</td>
<td>Continuous Descend Approach</td>
</tr>
<tr>
<td>CRIA</td>
<td>Critical Interaction Analysis</td>
</tr>
<tr>
<td>ENAV</td>
<td>Ente Nazionale Assistenza al Volo</td>
</tr>
<tr>
<td>E-TMA</td>
<td>Extended Terminal Manoeuvre Area</td>
</tr>
<tr>
<td>FIFO</td>
<td>First In First Out</td>
</tr>
<tr>
<td>FIR</td>
<td>Flight Information Region</td>
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<tr>
<td>HF</td>
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<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
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<td>LIRA</td>
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<td>Napoli Airport</td>
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<td>Pisa Airport</td>
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<td>Low Visibility Approach</td>
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<tr>
<td>MSP</td>
<td>Multi Sector Planning</td>
</tr>
<tr>
<td>NTZ</td>
<td>No Transgression Zone</td>
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<td>PMS</td>
<td>Point Merge System</td>
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<td>PRNAV</td>
<td>Precision Area Navigation</td>
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<td>RNAV</td>
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<td>RNP APCH</td>
<td>Required Navigation Performance Approach</td>
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<tr>
<td>RWY</td>
<td>Runway</td>
</tr>
<tr>
<td>SID</td>
<td>Standard Instrument Departure</td>
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<tr>
<td>SM</td>
<td>Sequence Manager</td>
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<tr>
<td>SME</td>
<td>Subject Matter Expert</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard Arrival</td>
</tr>
<tr>
<td>STCA</td>
<td>Short Term Conflict Alert</td>
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<tr>
<td>TLX</td>
<td>Task Load Index</td>
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<td>TMA</td>
<td>Terminal Area</td>
</tr>
<tr>
<td>TWR</td>
<td>Tower</td>
</tr>
<tr>
<td>WTC</td>
<td>Wake Turbulence Category</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

**DOCUMENT OVERVIEW** ............................................................................................................................ 1

**AUTHORS AND REVIEW PROCESS** ........................................................................................................... 2

**DOCUMENT APPROVAL** .............................................................................................................................. 3

**DOCUMENT CHANGES RECORD** ................................................................................................................ 4

**Acronyms and Abbreviations** ....................................................................................................................... 5

**Chapter 1 Introduction** ............................................................................................................................... 8

1.1 The Project .................................................................................................................................................. 9
1.2 The Operational Concept ......................................................................................................................... 11
1.3 The Operational Scenario ........................................................................................................................ 13
1.3.1 Runways 16L/R in use at LIRF ........................................................................................................... 13
1.3.2 Runways 34L/R in use at LIRF ........................................................................................................... 15
1.4 Roles and Working Methods .................................................................................................................. 18
1.5 The Simulation Room Layout ................................................................................................................. 21
1.6 Tools Available ....................................................................................................................................... 23

**Chapter 2 Evaluation Plan** .......................................................................................................................... 24

2.1 Objectives of the Prototyping Sessions ................................................................................................. 24
2.2 Hypotheses ............................................................................................................................................... 25
2.3 Validation Methodology ......................................................................................................................... 25
2.4 Validation Techniques ............................................................................................................................. 26
2.5 Scenarios ............................................................................................................................................... 27
2.6 Exercises ............................................................................................................................................... 29
2.7 Agenda ................................................................................................................................................ 30

**Chapter 3 Results of the Prototyping Sessions** ............................................................................................ 32

3.1 Introduction to the Results ....................................................................................................................... 33
3.2 Application of the Point Merge System Method .................................................................................... 34
  3.2.1 Use of PMS in case of high traffic load ............................................................................................ 35
  3.2.2 Use of PMS in case of low traffic load ............................................................................................ 43
  3.2.3 Transition from conventional method to PMS and vice versa ......................................................... 47
  3.2.4 Use of PMS in case of go around ..................................................................................................... 49
  3.2.5 Use of PMS in case of spacing increase .......................................................................................... 51
  3.2.6 Use of PMS in case of runway change ............................................................................................ 55
3.2.7 Use of the PMS method in case of radio failure .............................................................. 59
3.2.8 Use of PMS in case of bad weather and mixed equipped traffic ........................................ 60
3.2.9 Flexible use of the PMS method ..................................................................................... 63
3.3 Appropriateness of roles and working methods ..................................................................... 67
3.4 Impact on controllers’ workload ............................................................................................ 76
3.5 Appropriateness of the simulation room layout ...................................................................... 80
3.6 Appropriateness of Human Machine Interaction ...................................................................... 84
  3.6.1 Defects of missing information ........................................................................................ 84
  3.6.2 Limits of display settings .................................................................................................. 86

Chapter 4 Conclusions and Lesson Learnt .............................................................................. 89
Chapter 1
Introduction

This document contains the results of the first phase of the ENAV Point Merge System (PMS) project, aimed to assess the domain suitability and controllers’ initial acceptability of applying the PMS concept in Rome Terminal Area (TMA).

It presents the results of four prototyping sessions held at Rome Area Control Centre (ACC) in March, April, May and June 2008. During these prototyping sessions the PMS concept has been introduced in Rome TMA for the management of traffic to Fiumicino airport (LIRF), with runways configurations 16R/L and 34L/R and in both full runways configurations and single runway operations. The introduction of the PMS concept did not affect the traffic to Ciampino airport (LIRA) – also included in Rome TMA – that continued to be managed in conventional way.

The report makes up of 4 sections, presenting respectively:

• the introduction to the project and to the prototyping sessions (chapter 1)
• the evaluation plan applied during the prototyping sessions (chapter 2)
• the results of the prototyping sessions (chapter 3)
• conclusions and way forward (chapter 4)
1.1 The Project

The ENAV PMS Project aims to evaluate the domain suitability and user acceptability of introducing the PMS concept in Rome TMA, for the management of traffic to LIRF.

The project is managed by ENAV Headquarter, with extensive cooperation of Rome ACC and ENAV CNS/ATM Experimental Centre. Support is provided by Eurocontrol Experimental Centre and Headquarter. Deep Blue is responsible for Human Factors assessment.

The project makes up of two phases, consequential and strictly interdependent:

- Phase 1 – Small Scale Prototyping Sessions at Rome ACC
- Phase 2 – Large Scale Real-Time Simulation at ENAV CNS/ATM Experimental Centre

Phase 1 – Prototyping Sessions

The first phase – to which this report refers – focuses on the PMS introduction in the arrival sectors of Rome TMA. Possible effects on Extended TMA (E-TMA) sectors and/or on cooperation between E-TMA and TMA sectors are out of the scope of this first phase and will be investigated in Phase 2.

The first phase has been carried out at Rome ACC. It developed in four small scale prototyping sessions, in which the concept has been tested in different operational scenarios depending on the runway configurations in use in both LIRF and LIRA.

The following roadmap shows the calendar of the prototyping sessions.

<table>
<thead>
<tr>
<th>PROTOTYPING SESSION</th>
<th>TRAINING</th>
<th>RUNS</th>
<th>OPERATIONAL SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20\textsuperscript{th} March</td>
<td>25\textsuperscript{th} to 27\textsuperscript{th} March</td>
<td>16 L/R and 16L with no LIRA</td>
</tr>
<tr>
<td>2</td>
<td>17\textsuperscript{th} April</td>
<td>22\textsuperscript{nd} to 24\textsuperscript{th} April</td>
<td>16L/R and 16L with LIRA</td>
</tr>
<tr>
<td>3</td>
<td>15\textsuperscript{th} May</td>
<td>20\textsuperscript{th} to 22\textsuperscript{nd} May</td>
<td>34L/R and 34R with LIRA (RWY15)</td>
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<tr>
<td>4</td>
<td>No training</td>
<td>9\textsuperscript{th} to 12\textsuperscript{th} June</td>
<td>34L/R and 34R with LIRA (RWY33)</td>
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TAB.1 – Roadmap of the Prototyping Sessions carried out in Phase 1 of ENAV Point Merge System Project

In terms of operational scenario the first two prototyping sessions focused on runway configuration 16 R/L, while the following two focused on runway configuration 34 L/R.
An iterative and incremental validation approach has been applied, which had the twofold purpose to gradually introduce the new concept to the controllers and profiting by the results of the previous session to prepare the following one.

Following this approach the first prototyping session was based on a simplified operational scenario marked by lack of traffic destination LIRA, application of Continuous Descend Approach (CDA) within the triangles despite radar minima constraints and lack of departures from both LIRA and LIRF. The use of a simplified operational scenario was intended to allow the controllers involved in the prototyping session to purely focus on the operational concept under investigation. A more realistic and complete operational scenario has been then simulated in the following sessions, in which traffic to LIRA has been added to the traffic samples and radar minima constraints within the triangles have been taken into account.

Departures have not been simulated in this phase of the project due to possible interferences between the triangles and the current Standard Instrument Departures (SIDs).

**Phase 2 – Real Time Simulation**

The second phase of the project enlarges the scope of the investigation and considers the possible impact of PMS not only on Rome TMA sectors, but also on E-TMA sectors.

During this phase a large scale real-time simulation will be arranged and carried out at ENAV CNS/ATM Experimental Centre. The purpose of the simulation is to assess domain suitability and user acceptability of the PMS concept in a more complete operational scenario than the one used in phase 1. The operational scenario taken into consideration includes both TMA and E-TMA sectors. The traffic samples contain traffic to and from both LIRF and LIRA, as well as to and from some other minor airports situated in the Rome Flight Information Region (FIR) such as Napoli (LIRN), Pisa (LIRP), Firenze (LIRQ), Perugia (LIRZ). Also in this case PMS will be applied only to the traffic destination LIRF, while the traffic to the other airports will be managed in the conventional way.

In addition to PMS, Arrival Manager (AMAN) will be also introduced in the second phase of the project. Although AMAN is not mandatory for the use of PMS, it will be
proposed as a support for the pre-sequencing managed by E-TMA sectors controllers. The evaluation of the possible interoperability between AMAN and PMS is one of the main objectives of the second phase of the project.

### 1.2 The Operational Concept

The PMS operational concept applied in the project has been borrowed from the original one developed at the Eurocontrol Research Centre and represented in Fig.1.

![Point merge system – example with two inbound flows](image)

Fig. 1. Point merge system – example with two inbound flows

According to this operational concept, PMS is a new ATC technique aimed to facilitate the merging of traffic from a number of Area Navigation (RNAV) arrival routes.

The technique is based upon aircraft flying a quasi-arc, up to 30NM long, with a radius of 20+NM from the designated merge point. Each arc has a published altitude that the aircraft must have reached before establishing on the arc and a predefined speed to fly it. A pre-requisite for the effective application of the concept is that upstream sectors controllers hand the traffic over to the arrival sectors already steady and at constant and predefined speed.
In general the arc nearest to the merge point has the highest altitude while the other has the lowest altitude in order to make the descent of the traffic leaving the external sequencing leg free from traffic flying the internal one.

Each point of the sequencing leg is iso-distance from the merge point.

The controller clears the aircraft off the arc direct to the merge point when separation from the preceding aircraft is assured. After appreciating the aircraft turn to the merge point, and providing that the aircraft is clear of all the other traffic, the controller clears it to descend. CDA is applied in this phase, if the orographic characteristics of the area allow it. In alternative step descent is foreseen.

If the aircraft reaches the end of the arc without receiving a “direct to merge point” clearance, it turns automatically towards the merge point maintaining the current altitude. Final waypoint of each arc is recommended to be a “fly-over”, thereby providing the controller with an unambiguous turning point for Lost Communications aircraft while ensuring the maximum time to manage the traffic.

Unless the final approach is RNAV (Required Navigation Performance Approach - RNP APCH) the missed approach is conventional, with radar vectoring to place the aircraft back into the arrival stream.

Holding points are established prior to the arcs to cater for traffic peaks, missed Approaches, low visibility approach (LVP) operations and a temporary runway closure.

For the application of the PMS concept in Rome TMA, two triangles have been introduced in both operational scenarios RWY 34L/R and 16L/R.

One triangle is on the East, the other on the West. Each triangle is associated to one point merge and to one runway that it is intended to feed.

The basic principle to link triangles, point merges and runways is to make traffic from the East landing on RWY 16L/34R and traffic from the West landing on RWY16R/34L. Nevertheless considering the different landing rate of the two runways and the bearing of the traffic flows, runway change is allowed in specific situations, such as before entering in the triangles or flying inside a triangle to land on the other runway. The runway change has to be planned/coordinated by SM LIRF in order to profit by the capacity of both runways, avoid delays and/or satisfy specific pilots’ requests.

In case of single runway operations both triangles feed the runway in use and the
integration of the traffic flows is based on the “first in, first out” (FIFO) principle.

1.3 The Operational Scenario

Different operational scenarios have been simulated during the prototyping sessions. As already stated in par. 1.1:

- the first and second prototyping sessions were based on runway configuration 16L/R. The first one adopted a simplified operational scenario marked by no consideration of radar minima constraints within the triangles and traffic samples made up of only traffic inbound to LIRF. In the second one traffic to LIRA (RWY 33) and radar minima constraints have been added.

- the third and forth prototyping sessions were based on runway configuration 34R/L, with RWY 15 and 33 respectively in use in LIRA. In both cases radar minima constraints have been taken into consideration and traffic to LIRA was included in the traffic samples.

Traffic to LIRA, when present, was not managed with the PMS method, but in the conventional way.

For specific internal ENAV objectives, parallel independent approaches to LIRF were simulated during the prototyping sessions, even if not in operations yet.

1.3.1 Runways 16L/R in use at LIRF

The following Fig.2 represents the way the PMS concept has been applied in Rome TMA when runways 16 L/R are in use in LIRF and runway 15 is in use in LIRA. This operational scenario has been applied in the first two prototyping session, with the difference that in the first one the inbound traffic to LIRA (whose trajectory is depicted in magenta) was not present in the traffic samples.

The West triangle is associated to merge point FRANK (5.000 feet) and to runway 16R, while the East one is associated to STAIR (4.000 feet) and to runway 16L.

According to the operational concept applied, runway change can be performed using the ATC discretion routes (dot lines) or clearing the aircraft from FRANK to common point 16L, in case of traffic from the West landing on 16L (in both scenarios 16L/R and
16L single runway). From STAIR there is no connection with runway 16R. Thus, in principle, it is not possible to send the aircraft to common point 16R after STAIR.

**Fig.2 – the implementation of PMS with runways 16L/R**

Due to radar minima constraints in the East triangle, a step descent is foreseen in this area from the sequencing legs to FL90 and from FL90 to the point merge altitude.

Traffic destination LIRA is managed as follows:

- Using conventional ( ) STAR’s:
  1. **BOL3G** (BOL – CMP) FL90
  2. **ALAXI3F** (ALAXI – PEMAR – RA403 – URB) FL110 then FL100 to PEMAR
3. **VELIM3F** (VELIM – PEMAR – RA403 – URB) FL120 then FL100 to PEMAR
4. **OST3G** (OST – CMP) alt 6000ft
5. **ELKAP3F** (ELKAP – BIBEK – CMP) FL130

- Using Radar Vectors (###):
  
  Suggested Heading from BOL is 165° until crossing west abeam of STAIR, then direct URB for ILS15.

### 1.3.2 Runways 34L/R in use at LIRF

The following Fig.3 represents the way the PMS concept has been applied in Rome TMA when runways 34 L/R are in use in LIRF. A wind of 28kts direction 330 below FL110 has been simulated during the prototyping sessions in order to justify the use of this operational scenario.

The West triangle is associated to merge point VANIA (3.000 feet) and to runway 34L, while the East one is associated to SHARA (4.000 or 5.000 feet depending on the runway in use in LIRA) and to runway 34R.

According to the operational concept applied, runway change can be performed using the ATC discretion routes (dot lines) or clearing the aircraft from VANIA to common point 34R, in case of traffic from the West landing on RWY 34R (in both scenarios 34L/R and 34R single runway). From SHARA there is no connection with runway 34L. Thus, in principle, it is not possible to send the aircraft to common point 34L after SHARA.

Traffic destination LIRA is managed in a different way depending on the runway in use. With runway 33 VOR “A” procedures has to be applied. It is depicted in the following approach chart in Fig.4. The only change with respect to the original procedure is the starting altitude, which is 4000ft instead of 4500ft, to remain clear of the final eastern paths to the merge point (SHARA).

With runway 15 in LIRA instead the traffic to LIRA can be managed as follows:
- Using conventional STAR’s:
  1. **BOL3G** (BOL – CMP) FL90
2. **ALAXI3F** (ALAXI – PEMAR – RA403 – URB) FL110 then FL100 to PEMAR
3. **VELIM3F** (VELIM – PEMAR – RA403 – URB) FL120 then FL100 to PEMAR
4. **OST3G** (OST – CMP) alt 6000ft
5. **ELKAP3F** (ELKAP – BIBEK – CMP) FL130

- Using Radar Vectors as appropriate.
Fig. 4 - VOR "A" RWY33 Approach Chart
1.4 **Roles and Working Methods**

The adoption of the operational concept described in par.1.2 and 1.3 required some changes in the working methods applied in Rome TMA for the management of arrival traffic to LIRF.

These changes, concerning both E-TMA and TMA Sectors, were quite limited (see details below), as roles and working methods have been designed in order to be as much coherent as possible with those currently in use in Rome ACC.

This choice of continuity between the two operational realities had the twofold purpose to allow the controllers to:

- be deeply involved in the definition of the best way to apply the new technique
- perceive the new technique as an evolution of the way the traffic is currently managed, instead of a radical revolution, thus increasing the acceptability of the technique itself.

**E-TMA sector controllers**

E-TMA sector controllers (managed as a feed sector during the prototyping sessions) conform to standard roles in use in Rome ACC. The only modifications introduced in their working methods concern the requirements to:

- pre-sequence the arrival traffic at a minimum distance of 7NM
- provide TMA sectors with arrival traffic at a pre-defined flight level and speed reported on the maps (par.1.3)
- reach both the conditions above at least 10NM prior the aircraft enters the sequencing leg

Traffic to LIRA has to be spaced as in normal operations (at least 7NM).

These changes in the working methods of E-TMA sector controllers are considered a pre-requisite for the effective application of the operational concept at concern.

**SM LIRF**

Being responsible for the arrival traffic management in the overall simulated airspace, SM LIRF has to monitor a wide working area.
His main task is to balance east and west flows of traffic in respect of the defined constraints (e.g. landing rate, WTC, slot insertion,…), and handle potential unexpected situation.

SM LIRF optimises the sequence giving instructions to E-TMA sector (NW, NE, US, DP), taking into account any other possible re-routing which may help in balancing the traffic and reducing the overall delay.

In case of single RWY operation, SM LIRF coordinates the gap where to insert the aircraft with SM LIRA.

In addition, in case of full runways configuration, he informs SM LIRA, TNW and ARW of the traffic flying the west envelope expected to land on the other runway. He also informs SM LIRA of traffic landing in LIRA coming from West. For this traffic coordination with SM LIRA may also be required in order to defined the most suitable route to follow.

**SM LIRA**

Being responsible for the arrival traffic management associated to LIRA, SM LIRA determines the strategy to keep the arrival flow to LIRA apart and independent from the envelope of paths which are LIRF dedicated and coordinates all the inbound warning and releases with LIRA TWR.

Moreover he:

- informs ARE of the traffic flying the west envelope expected to land on east runway and all the traffic landing in LIRA coming from the other sector (west).
- coordinates any potential runway change which may occur after the merge points with LIRF TWR giving sudden warning to SM LIRF.
- informs SM LIRF in case of unpredicted runway change
- in case of single RWY operation mode, informs both AR of the traffic flying from the west envelope.

**TNW Sector (freq. 125.500)**

TNW Controller issues the “Turn left/right direct to merge point (FRANK/VANIA) and descend to (5000 or 3000 ft)” instructions to the proper aircraft using the range ring
arcs to assess the appropriate spacing from the preceding aircraft.

After appreciating the turn he hands the traffic over to ARW sector.

A different defined spacing is applied according to the landing rate requested.

In RWY 16L/R operational scenario TNW has to deal in a particular way with the traffic destination LIRA coming from the West. The traffic to LIRA flying ELKAP3F has to be cleared not below FL130 until crossing the West triangle, then it can be cleared to further descend to FL 100 as appropriate. Leaving the West triangle TNW hands this traffic over to ARE.

**TNE Sector (freq. 127.950)**

TNE Controller issues the “Turn left/right direct to merge point (STAIR/SHARA) and descend to (4000 or 5000 ft)” instructions to the proper aircraft using the range ring arcs to assess the appropriate spacing from the preceding aircraft.

After appreciating the turn the traffic is sent in contact with ARE sector.

A different defined spacing is applied according to the landing rate requested.

In RWY 16L/R operational scenario TNE has to deal with the step descend that is necessary in a part of the triangle. In this case has clear the aircraft to descend to FL90 and contact ARE, instead of clearing it to descend directly to STAIR.

In RWY 34L/R operational scenario TNE has to deal in a particular way with the traffic destination LIRA coming from the East. The traffic to LIRA flying ALXI/VELIM3F has to be cleared not below FL130 until crossing the East triangle, then it can be cleared to further descend to FL 100 as appropriate. Leaving the East triangle TNE hands the traffic over to ARE.

**ARW (freq. 119.200)**

ARW Controller optimises 16R/34L sequence by using the PMS technique as appropriate. Upon receiving the traffic in contact leaving the sequencing legs, he monitors the aircraft descent issued by TNW controller and adjusts the speed if necessary to optimise the required spacing.

He also provides vertical separation between aircraft in independent parallel approaches until they are within the NTZ, and established on the respective ILS
localiser course.

When traffic landing on 16L/34R is managed by ARW:

- vertical separation is applied between traffic landing on the two runways
- frequency change is provided as soon as possible after the point merge and/or when safely appropriate.

**ARE (freq. 131.250)**

ARE Controller optimises 16L/34R sequence by using the PMS technique as appropriate. Upon receiving the traffic in contact leaving the sequencing legs, he monitors the aircraft descent issued by TNE controller and adjusts the speed if necessary to optimise the required spacing.

He also provides vertical separation between aircraft in independent parallel approaches until they are within the NTZ, and established on the respective ILS localiser course.

In both single runway and full runway configurations ARE is responsible for building the sequence to LIRA using STARs and radar technique as appropriate according to the requested landing rate. Traffic destination LIRA has been previously pre-arranged by SM LRA and pre-sequenced by TNE when sent in contact to ARE.

### 1.5 The Simulation Room Layout

Two simulation room layouts have been tested during the prototyping sessions. The one proposed at the beginning of the study and applied in the first three prototyping sessions is represented in Fig.5 and Fig.6.

![Simulation Room Layout](image-url)
The adoption of this simulation room layout has been constrained to be in line with the real operative room layout, according to which no more than two controller working positions could be located on each desk. This is the reason why the working positions are coupled, with gaps between the three couples. Given this constraint, the controllers working positions have been set out in order to allow:

- ARW and ARE controllers to work closely (a must with parallel independent approach)
- each SM to stay in between the TN and AR controllers of his area

This simulation room layout requires SM LIRF and SM LIRA to coordinate by phone.

In case of single runway scenario, this operational room layout was slightly different. As represented in Fig.6 there is one TN controller per each triangle, both SM LIRF and LIRA and one unique AR sector in which both ARE and ARW collapse.

![Fig.6 – the simulation room layout tested in the first three prototyping sessions in single runway configuration](image)

The studies provided homogenous results about the effectiveness of this room layout. In all the studies it revealed not perfectly suitable for the effective application of PMS in Rome TMA (detailed results are in par.3.5) and worth to be changed.

An alternative room layout has been introduced and tested during the fourth and last prototyping session (Fig.7 and Fig.8), providing more positive results.

![Fig.7 – alternative simulation room layout in full runways configuration](image)
These alternative layouts aim to better support the application of the controllers’ working methods (par.3.3). In particular they are intended to facilitate SM LIRF in coordinating with TN controllers and SM LIRA in coordinating with AR controllers.

In order to allow SM LIRA to easily coordinate the management of traffic to LIRA with both ARE and TNE, the order of ARE and ARW has been reverted with respect to the geographical orientation of their sectors. In fact ARE is on the left, while ARW is on the right.

Results about the effectiveness of this room layout are in par.3.5.

1.6 Tools Available

The tools available in the simulation room were almost the same currently in use in Rome ACC control room. The only difference concerned the paper strips that have not been used during the prototyping sessions.

As in the control room, Short Term Conflict Alert (STCA) and Multi Sector Planner (MSP)\(^1\) were not available in TMA sectors during the prototyping sessions.

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\(^1\) MSP is the technical enable that allows to associate one controller working position (i.e. the SM one) to the volumes of airspace of more than one sector. Due to the lack of this tool, the volume of airspace of TNE, TNW, ARE and ARW were not associated to their respective sector and at the same time collapsed in SM positions. The four volumes were then unified in one unique volume, associated to all the controllers working positions. As consequence of this limitation TN Controllers had to manually update the status of the flight on their radar screen as soon as transferring the aircraft to the AR.
Chapter 2
Evaluation Plan

This chapter presents the evaluation plan applied in the prototyping sessions. The evaluation plan has been developed on the basis of the project objectives and of the operational concept described in previous chapter. The same evaluation plan has been almost applied in all the prototyping sessions in order to foster the comparison of their results.

2.1 Objectives of the Prototyping Sessions

The objective of the prototyping sessions was to assess the domain suitability and controllers’ acceptability of the PMS concept implemented in Rome TMA.

The assessment mainly focused on the following Human Factors (HF) issues:

- working methods, procedures, roles and responsibilities
- workload
- working layout
- Human Machine Interaction
2.2 **Hypotheses**

Introducing the PMS technique in Rome TMA the following outcomes were expected in terms of operability:

- standardisation of the arrival management
- effective use of the runway capacity
- acceptable workload

These hypotheses have been purposely defined in order not to be comparative with the current operational reality of Roma ACC. The purpose of the phase 1 was to evaluate users’ acceptability and domain suitability of the application of the new PMS technique in Rome TMA. The comparison with the current operations was considered out of the scope of this phase and not adequate at this preliminary stage. The choice of not performing a comparative study had moreover the purpose to fully profit by the short duration of each session to apply and test the new technique (par.2.7), without the need to run baseline exercises as the comparative study would have required.

2.3 **Validation Methodology**

The CRIA© validation methodology has been applied during the preparation, conduct and analysis of the prototyping sessions reported.

CRIA© is a HF methodology for the investigation of safety critical systems. The main goal of CRIA© is to analyse the interactions between the human component of a system and the other system components: procedures, equipment, other humans, organisational aspects. Such analysis brings to the identification of strength and weakness points of the system as a whole, so that mitigation actions can be studied to reduce the probability of the occurrence and the severity of critical events within the system.

CRIA© has its theoretical foundation in the distributed cognition theory that claims that human cognition is not exclusively characterised by the brain activity but is distributed among the brain and the artefacts employed carrying out the activity. This idea dates back to the cultural-historical school asserting that all kinds of conscious human activities are structured by the use of external tools.
Following this approach, key features of CRIA© are:

- the recognition of the importance of all mediating artefacts both material (such as flight deck technologies, checklist, manuals, etc) and immaterial (practices, operational procedures, competencies, Company guidelines, legislation, etc.) used by the human being to carry out the activity.

- the recognition of the importance of the cultural and organisational milieu in which human activities develop.

- the use of structured narrative scenarios to represent the interactions between human actors and mediating artefacts, by preserving realism of the context.

CRIA© has been successfully used in real time simulations, shadow mode trials and live flight trials. It has proved to be a flexible and adaptable methodology to evaluate new concepts and tools, as well as minor changes to the current operational situation.

### 2.4 Validation Techniques

During the prototyping sessions the CRIA© validation methodology has been applied in combination with two classes of validation techniques, based respectively on the observation of the controllers’ work during the runs and on the collection of their feedback at the end of the runs.

During the runs the observation consisted in:

- human factors observation, focused on the HF issues listed in par.2.1
- Subject Matter Expert (SME) observation, aimed at investigating the impact of the new PMS application on the controllers’ work and on the effectiveness of the traffic management
- video-recording of the runs

The post run feedback collection has been instead based on:

- post-exercise questionnaire (based on NASA TLX) for the evaluation of the workload perceived by each controller during the run
- post-exercise debriefing, involving all the participants in the simulation. The debriefing was a useful occasion to get the controllers’ feedback and freely
discuss about the effectiveness and acceptability of the PMS technique.

Qualitative data have been gathered by means of these techniques. Quantitative data have not been recorded due to limitations in the simulation platform.

2.5 Scenarios

As mentioned above, the use of narrative scenarios is one of the key aspects of CRIA®. Scenarios present the advantage to recreate events or aspects of the work that are relevant for the analysis in a realistic operational environment. They often put together the information coming from different sources (i.e. field observation, documents, interviews, story telling, etc.) and from different persons (i.e. controllers, subject matter experts, human factors analysts, developers, etc.) with the final aim to analyse the potential impact that a new cognitive artefact (i.e. a procedure, a tool, a new work organisation, etc.) can have on the safety critical system.

Using scenarios instead of exercises has the advantages to allow the analysis of specific situations that otherwise may not happen and to control the experimental setting, knowing in advance the event that is going to happen.

For the preparation of the scenarios used during the prototyping session the following sources have been used:

- documentation about the arrival management in Rome TMA
- documentation about the PMS operational concept
- interviews with operational experts involved in the project

This investigation brought to the identification of a number of relevant events, that have been then formulated as scenarios, associated to the exercises and executed during predefined runs of the prototyping sessions.

Two classes of scenarios have been used:

- basic scenarios, concerning nominal events that can happen quite often
- exceptional scenarios, concerning non nominal events that can happen quite rarely and reveal critical for the application of the PMS method.

Basic scenarios have been executed, in the same exercise, in all the studies. They
have been repeated several times during each prototyping session, in different traffic conditions and with different traffic loads.

Exceptional scenarios have been introduced from the second prototyping session on. Two of these exceptional scenarios have been executed during the second and third prototyping sessions. The others have been tested in the forth prototyping session. They have been executed once in each of the prototyping sessions interested.

The following table summarises the scenarios executed in the studied.

<table>
<thead>
<tr>
<th>CLASSES</th>
<th>SCENARIOS</th>
<th>PROTOTYPING SESSIONS</th>
</tr>
</thead>
</table>
| BASIC SCENARIOS WITH NOMINAL EVENTS | Scenario 1  
In single runway operations LIRF TWR requires a 12NM spacing on runway 16L/34R for inspection | 1-2-3-4 |
| | Scenario 2  
In full runways configuration LIRF TWR requires a 12NM spacing on RWY 16L/34R for inspection | 1-2-3-4 |
| | Scenario 3  
In full runways configuration LIRF TWR requires 8NM spacing on runway 16L/34R due to radar problems | 1-2-3-4 |
| | Scenario 4  
In full runways configuration LIRF TWR requires 8NM spacing on runway 16R/34L due to departures | 1-2-3-4 |
| | Scenario 5  
In full runways configuration one aircraft from South-East asks the controller to land on runway 16R/34L | 1-2-3-4 |
| | Scenario 6  
In full runways configuration one aircraft from North-West asks the controller to land on runway 16L/34R | 1-2-3-4 |
| | Scenario 7  
In full runways configuration one aircraft landing on runway 16L/34R does not establish on the localizer | 1-2-3-4 |
<table>
<thead>
<tr>
<th>Scenario 8</th>
<th>2-3</th>
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</thead>
<tbody>
<tr>
<td>In full runways configuration radio failure of one aircraft in the East triangle</td>
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<tr>
<th>Scenario 9</th>
<th>2-3</th>
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<tbody>
<tr>
<td>In full runways configuration bad weather affecting the East triangle</td>
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<tr>
<th>Scenario 10</th>
<th>4</th>
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<tbody>
<tr>
<td>In full runways configuration transition from radar vectoring procedures to PMS</td>
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<table>
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<tr>
<th>Scenario 11</th>
<th>4</th>
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</thead>
<tbody>
<tr>
<td>In full runways configuration E-TMA sectors do not succeed in pre-sequencing the inbound traffic as required for the application of the PMS method</td>
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<table>
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<tr>
<th>Scenario 12</th>
<th>4</th>
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<tbody>
<tr>
<td>In full runways configuration, closure of runway 34L</td>
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<table>
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<tr>
<th>Scenario 13</th>
<th>4</th>
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<tbody>
<tr>
<td>In full runways configuration, management of a few traffic not PRNAV equipped</td>
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</table>

<table>
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<tr>
<th>Scenario 14</th>
<th>4</th>
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<tbody>
<tr>
<td>Sudden transition from PMS to radar vectoring due to DME Off</td>
<td></td>
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</tbody>
</table>

**TAB.2 – the Scenarios executed in the prototyping sessions**

### 2.6 Exercises

A set of 9 exercises has been developed for the prototyping sessions using one traffic sample recorded at Rome ACC as a reference.

The nine exercises were different one from the others and realistic, even if modified with respect to the original traffic sample in order to have in each exercise a specific traffic density and often specific traffic conditions suitable for the scenarios execution.

Some Heavy traffic (in realistic percentage) and no Light traffic were included in the traffic samples. The traffic was intended to be 100% PRNAV equipped, but for the
exercise including scenario 13 (par.2.5). This choice was based on the consideration that at present more than 90% of the traffic interesting Rome TMA is PRNAV equipped (source Eurocontrol).

Three traffic densities have been implemented in the exercises, on the basis of the current capacity of LIRF (37 and 54 aircraft/h respectively in single runway and full runways operations) and LIRA (11 aircraft/h). The three densities were:

- Density 1 (aircraft/h): LIRF 40 + LIRA 8
- Density 2 (aircraft/h): LIRF 50 + LIRA 11
- Density 3 (aircraft/h): LIRF 60 + LIRA 15

Densities 1, 2 and 3 have been tested in full runways configurations, while only density 1 has been applied in single runway operations. In fact:

- two exercises have been produced to be executed in single runway operations, both with traffic density 1 (40 aircraft/h)
- 7 exercises have been planned in full runways configuration, among which 2 exercises with density 1 (40 aircraft/h), 3 with density 2 (50 aircraft/h) and 2 with density 3 (60 aircraft/h)
- three exercises out of nine – namely one per each traffic density– have been planned to be executed without scenarios; in the others one or more scenarios have been planned to happen.

Each exercise had a 60 minutes duration. In order not to bias the results:

- a seating plan has been produced, defining the controllers’ turn over on the working positions
- controllers have been instructed to behave in a realistic way.

### 2.7 Agenda

The prototyping sessions lasted 4 working days each. The first day was generally of training, but for the fourth and last prototyping session in which the training has not been executed. A minimum of nine exercises has been executed in each prototyping session. The agenda of the studies was almost similar, with minor differences due to
organisational constraints. The agendas were based on the following principles:

- each day started with a briefing involving the simulation staff and the controllers participating in the study
- each exercise lasted about one hour and was followed by a post-exercise questionnaire and a collective debriefing
- three exercises a day were schedule
- the exercises were arranged in order to limit the effects of possible biases such as learning effects and tiredness
- the controllers rotation on the working positions was regulated by a seating plan aiming to make them covering all the positions in an homogeneous way
Chapter 3
Results of the Prototyping Sessions

This chapter presents the results of the prototyping sessions held at Rome ACC with the purpose of evaluating the users’ acceptability and domain suitability of applying the PMS technique in Rome TMA.

As already discussed in previous chapters, the focus of the study was on the effects of the point merge method on the TMA sectors when runways 16L/R and 34L/R are in use in LIRF and runways 15 and 33 are in use in LIRA.

The choice of not considering its possible impact on upstream sectors was due to the incremental approach adopted in the project (par.1.1). According to the project organisation this first phase (to which this report refers) focuses just on TMA aspects, while phase 2 enlarges the scope of the analysis and investigates the overall impact of PMS in both TMA and upstream sectors.
3.1 Introduction to the Results

The prototyping sessions produced positive results on the users' acceptability and domain suitability of applying the PMS technique in both the simulated operational scenarios of Rome TMA.

The controllers involved in the studies found the method comfortable, safe, accurate and easy to learn and to apply. In very short time they became familiar with it and able to apply it properly and effectively, even under high traffic load and in case of non nominal events. They considered the new technique suitable to and easy to accept in Rome TMA arrival sectors. They also tended to perceive it as the evolution of the current method based on radar vectoring as result of the introduction of the PRNAV capability, rather than as a radical revolution of the arrival traffic management.

In their opinion the adoption of this method is likely to yield the following advantages:

- standardisation of the controllers performances, thus implying a standard high quality of the traffic management, less conditioned by personal skills and one’s own tolerance of traffic density and complexity
- improved teamwork, since the standardisation of the work allows to predict and anticipate the colleague’s behaviour, expectations and needs
- general reduction of controller cognitive workload in all TMA sectors, since the standard way of managing the arrival traffic simplifies the work and reduces the need for problem solving, continuous monitoring, R/T and phone communication
- general high level of job satisfaction in the controllers, since the less creativity required to manage the arrival traffic is counterbalanced by evident positive results in terms of spacing and usage of runway capacity.

They also highlighted some drawbacks of the PMS technique, among which the following ones are worth to be reported:

- loss of flexibility with respect to the current open loop vectors technique
- conditioned applicability in certain circumstances (i.e. bad weather conditions impairing the use of both triangles and point merges), that entails the need for radar vectoring to continue to be applied
• concurrent application of radar vectoring and PMS method in case of traffic not 100% PRNAV equipped
• possible impact on the controllers workload in E-TMA sectors

The controllers involved in the studies tended to accept these drawbacks as tolerable side effects of the PMS technique. They were conscious of these limitations, but did not consider them as limitative as to impair the acceptability of the technique itself and/or its effectiveness. The management of non nominal events (such as bad weather, mixed equipped traffic samples and transition from PMS to radar vectoring and vice versa) confirmed these results.

The following paragraphs present the detailed results of the prototyping session. These results have been structured in five paragraphs, discussing respectively about:
• the application of the PMS method during the study
• the appropriateness of the roles and working methods applied
• the impact of the PMS technique on controllers’ workload
• the appropriateness of the working layout adopted
• aspects related to Human Machine Interaction

Recommendations and way forward for the next stage of the project are included.

### 3.2 Application of the Point Merge System Method

The controllers involved in the studies appreciated the PMS method proposed in the project, considering it as an effective means to reduce the complexity of the arrival traffic management in Rome TMA by taking advantage of aircraft PRNAV capabilities.

The provision of triangles, sequencing legs and distance ring, together with the associated rules and working methods, was perceived as a powerful -and at the same time simple- means to externalise the controllers’ knowledge, distribute it in the operational environment, structure the controllers’ work in a standard way and reduce their cognitive workload.

The results of the prototyping sessions are extremely homogenous. They concern the use of the method in a variety of cases, among which:
• high traffic load
• low traffic load
• go around procedure
• runway change
• spacing increase
• radio failure
• bad weather
• runway closure
• transition from PMS to conventional method and vice versa
• inadequate pre-sequencing
• mixed equipped traffic

They are also coherent in highlighting the possibility of a flexible use of the method.

3.2.1 Use of PMS in case of high traffic load

With high traffic load the studies have highlighted that the amount of traffic in the triangle is a key element for the effective use of the PMS method. In case of high traffic load, in fact, both too busy and not busy enough triangles may lead to disappointing results in terms of controllers’ workload and effective use of the runway capacity.

The conclusion to which the controllers finally came out during the studies was that for the successful application of the method the triangles should be completely and adequately full.

In order to reach the goal of completely and adequately full triangles they defined some strategies, concerning:

• the definition of triangles capacity
• the definition of a rule for the use of the sequencing leg
• the difficulty of AR controllers to be compliant with the standard PMS rules as alarm bell for too full triangles.
All these strategies aim to standardise the way the traffic is managed in the first part of the PMS procedure, concerning the entrance in the sequencing leg and the navigation through it. The set of principles on which the method is based (namely pre-sequencing, first in first out and use of distance rings) though generally sufficient to effectively use it, does not seem complete in case of high traffic load. A further rule seems to be necessary, concerning the control of the traffic load in the triangles and the traffic balancing on the two runways.

In the following there is a description of the three strategies defined during the prototyping sessions.

**Triangle Capacity**

In order to reach the goal of completely and adequately full triangles in case of high traffic load, the first strategy proposed by the controllers involved in the studies was to define a maximum triangles capacity to be used to regulate the access to the triangles themselves. This strategy is intended to avoid both situations of triangles overload and triangles not busy enough.

With RWY 16L/R the triangles capacity has been set at 13 aircraft to be included from the sequencing leg to the localiser interception, when the separation is 3NM on 16L and 6/8 NM on 16R. It is intended to be made up of 10 aircraft in the airspace from the sequencing legs to the merge point plus 3 aircraft in the airspace from the merge point to the localiser. This capacity is comprehensive of the traffic in both the triangles in case of single runway operations, while it refers to only the East triangle in case of two runways in use (separation at touchdown 3NM). The capacity of the West triangle is defined on the basis of the same principle but depends on the spacing requested among the aircraft landing on RWY 16R that tends to be larger and more variable than on the East.

With RWY 34L/R a different triangle capacity has been defined.

As already stated in par. 1.3, a wind value of 330°/28Kts has been simulated in the third and fourth prototyping sessions in order to justify the use of this runway configuration. The studies pointed out evident effects of the wind on the traffic performances. In particular they highlighted that a separation of 6/7NM is required within the East triangle in order to have a final separation of 3NM at touchdown. This
spacing inevitably affects the triangle capacity that has to be set accordingly. During the study the number has been set at 10 aircraft, 8 of which in the airspace from the sequencing legs to the merge point plus 2 aircraft in the airspace from the merge point to the localiser. Also in this case the capacity is comprehensive of the traffic in both the triangles in case of single runway operations, while it refers to only the East triangle in case of two runways in use.

It is interesting to notice that the introduction of the triangles capacity had the clear effect of changing the controllers’ working methods, particularly those of the SM LIRF. He is responsible for evaluating whether the amount of incoming traffic fits with the triangles capacity or not and to decide how to intervene in case of incoming traffic exceeding the triangle capacity.

The provision of the triangle capacity supports him in both these activities since just counting the incoming traffic allows him to:

- check whether an action is required because the traffic is going to exceed the triangle capacity
- (in case of full runways configuration) check whether there is room for traffic insertion in the other triangle or it is preferable to stop the traffic in holding outside the sequencing leg.

The application of this additional working method during the prototyping sessions revealed effective. The SM LIRF considered the rule very simple and effective to apply, while TN and AR sectors controllers appreciated the positive effect that the new rule produced on their workload and in terms of spacing.

This modification of the SM LIRF’s working methods introduced also a new idea of runway balancing, no more associated to the controllers’ workload but on the triangles workload. In the current operational environment of Rome TMA the Coordinator (correspondent to SM LIRF in the prototyping study) allocates the traffic to the runways in order to balance the workload of East and West TMA controllers. In the PMS scenario the runway balancing is instead a strategy applied -if possible considering the runways configuration in use- when the traffic incoming to a certain triangle exceeds its capacity. In the PMS operational scenario the focus seems to be on the triangles capacity, to which an acceptable level of controllers’ workload is
Interferences with traffic to LIRA have been noticed. With limited amount of traffic to Ciampino the rule of the maximum triangle capacity has proven to be applicable in an easy and effective way. Conversely with high traffic load to both Fiumicino and Ciampino airports, several cases have been observed in which SM LIRF has decided not to make optimum use of the East triangle capacity by:

- rerouting the traffic from East to the West triangle and runway
- rerouting the traffic from East to the other triangle even if keeping it landing on the East runway
- allowing West TMA controllers to manage the traffic landing on the east runway in the West triangle

This choice was intended to ensure East TMA controllers (namely TNE and ARE) a suitable level of workload, with at the same time acceptable penalisation of the traffic. With high traffic load East TMA controllers had to manage not only the traffic to LIRF in the East triangle but also the traffic to LIRA, this latter requiring the application of radar vectoring technique. The maximum triangle capacity, though ensuring the efficient use of the runway capacity in LIRF, in these cases would have probably overloaded TNE and ARE controllers and this outcome was considered unacceptable. For this reason SM LIRF decided to reduce the amount of traffic managed in the East TMA sectors. Between stopping the traffic to LIRA in holding and not to make the most of the triangle capacity, he considered the second option easier to manage, more efficient and thus preferable.

Unfortunately the line of reasoning used to make this decision when working as SM LIRF was not as straightforward as for the runway capacity. For sure the choice of not making maximum use of the east triangle capacity was left to the SM judgment and was based on individual factors such as:

- SM LIRF attention to TNE and ARE controllers workload
- TNE and ARE controllers’ own workload tolerance and externalisation

No rules have been put forward to standardise this behaviour. However one case has been observed during the third prototyping session in which the workload tolerance of
the controller acting as SM LIRF brought him to underestimate the workload of East TMA controllers and not to intervene, with negative consequences in terms of traffic management. This case leads to assume that besides the triangles capacity also a maximum capacity of the East TMA sectors should be defined, taking into consideration both traffic to LIRF and to LIRA.

The recommendation for the next stage of the project is to deeply discuss the topic of East TMA sectors capacity in case of high traffic load to both LIRF and LIRA airport and the link between it and the triangles capacity.

**Use of the sequencing leg: the traffic lights metaphor**

Defining the triangles capacity has the purpose to optimise the amount of traffic within the triangle, thus avoiding problems of triangles overload and unnecessary holdings associated to triangles not busy enough.

Another strategy came out during the studies, which has analogous purposes. It concerns the use of the sequencing leg as indicator of the triangle workload and trigger for SM LIRF intervention.

According to the controllers’ opinion the less the aircraft flies the sequencing leg, the more the triangle is empty and the traffic management smooth. Conversely the more the triangle is busy, the more the aircraft flies the sequencing leg passing from one segment to the following one.

As shown in par. 1.3, three segments make up the quasi-arc of the sequencing leg. During the studies the controllers tended to consider the point of the sequencing leg where the direct to merge point instruction has been issued as an indication of the traffic load in the triangles. If the traffic receives the instruction:

- as soon as entering the sequencing leg, the traffic load is considered quite low and the traffic management smooth
- in the second segment of the quasi-arc the traffic load is considered higher and requiring to be monitored by SM LIRF
- in the third segment of the quasi-arc, the traffic load is quite high in the triangle and SM LIRF has to intervene.

The traffic lights metaphor has been used to describe this working method:
• the first segment corresponds to green light: the traffic proceeds smooth and no problems are envisaged

• the second segment corresponds to orange light: the traffic management is still smooth but the SM LIRF is required to pay attention

• the third segment corresponds to red light: the triangle is going to be overloaded and the SM LIRF has to intervene in order to limit the access to it.

The introduction of the triangle capacity has the aim to maintain almost always green or at least orange light. Regulating the amount of traffic entering the triangle has in fact the purpose to avoid cases of triangle overload. As a proof of its effectiveness after the application of the triangle capacity during the study most of the traffic received the “direct to” instruction while in the first or in second segment of the sequencing leg, depending on the traffic load. Very few aircraft have been observed flying the third segment of the sequencing leg. It generally happened in particular cases, such as go around, increase of landing spacing, etc. However in these cases the availability of a further rule – the traffic light metaphor- to properly manage the traffic in the triangle revealed effective.

The two strategies intervene at different stages of the process of the arrival traffic management. The first one - triangle capacity - triggers the SM LIRF intervention on aircraft not yet in the triangles, while the second one - traffic light metaphor - triggers his attention on aircraft in the sequencing leg.

Despite the respect of the triangles capacity, it may happen that a certain aircraft arrives in the third part of the sequencing leg, for causes that are external to the SM LIRF behaviour (i.e. problems in the pre-sequencing, go around, increase of spacing, temporary runway closure, etc.). In these cases SM LIRF has to intervene and the aircraft position in the sequencing leg is a valuable trigger for him.

A subject of discussion in this respect concerns how to manage the traffic arriving at the end of the sequencing leg and not able to automatically turn to the merge point. This issue has been often discussed during all the studies. Three main options have been proposed, according to which, arriving at the end of the sequencing leg the aircraft that cannot turn to the merge point:

• is radar vectored outside the triangle
• holds on a dedicated holding point foreseen at the end of the sequencing leg
• enters in the other sequencing leg and navigates through it at a spare level.

The application of the first option revealed ineffective during the studies. It generally complicates quite a lot the traffic management, presenting effects not only on the traffic being radar vectored but also on the rest of the traffic within the triangles. Often radar vectoring one aircraft that has arrived at the end of the sequencing leg means for the controllers starting trying to create a hole in the sequence to re-insert it. The consequences are that the PMS method is no more used effectively, the other controllers lose the ability to anticipate the TN and AR controllers' behaviour and often the rest of the traffic has to be radar vectored as well.

The second option, namely the introduction of holding point at the end of the sequencing leg, has been often discussed and never tried. The opinion of the controllers involved in the studies is that the way the PMS concept has been implemented in Rome TMA does not allow to foresee effective holding point at the end of the sequencing legs.

The third option, based on the traffic re-insertion into the sequencing leg at a spare level, seems to be the most applicable and effective. It allows the controllers to keep using the PMS system effectively – and thus proving by its benefits –, with at the same time an almost limited penalisation for the traffic concerned. The strategy however has not been applied during the studies.

**Traffic management within the triangle as ring bells for triangle overload**

The previous paragraph has discussed the use of the sequencing leg as indicator of the triangle workload and trigger for SM LIRF intervention.

Another strategy with similar purposes concerns the traffic management within the triangle as indicator of triangle workload and trigger for SM LIRF intervention.

As stated in par. 1.4, the working methods of AR controllers are very straightforward if the separation among the traffic is appropriate. When the traffic is in the triangle they just have to monitor the aircraft descent and adjust the sequence by means of pre-defined speed adjustments.

The problem arises if the spacing is not appropriate because in this case the triangle
does not afford a fair room for manoeuvre. All the studies have highlighted that the most appropriate strategy to cope with inappropriate spacing within the triangle is to remove the traffic from the triangle and re-insert it into the sequencing leg. This strategy in fact penalises just the traffic concerned, without at the same time compromising the effective use of the PMS method or the rest of the traffic. Other strategies tested during the studies, such as radar vectoring and/or speed adjustments to values that are far lower than those defined in the working methods, produced negative impacts on the whole traffic management. Radar vectoring – unless really occasional and limited – often implies the need for applying radar vectoring to all the traffic with consequences in terms of AR controllers workload, situational awareness of TN controllers and SMs and effective use of the PMS method. Speed reduction, tends instead to slow down the sequence, with difficulties for the controllers in managing the traffic in the sequencing legs and consequent triangle overload.

Even if the effective strategy to cope with this problem has been identified, its application should be considered a recovery procedure. It is important that further strategies are applied in order to avoid the problem to arise. Triangle capacity and use of sequencing legs as indicator of triangle workload are definitely useful in this respect. In addition the way the traffic is managed within the triangle can be also used as indicator of the triangle workload and trigger for SM LIRF. The intervention of SM LIRF may be triggered in fact not only by TN controllers’ actions concerning the use of the sequencing leg but also by AR controllers’ actions intended to cope with inappropriate spacing within the triangle. Triggers can be actions such as traffic removal from the triangle and reinsertion in the sequencing leg or, worst, radar vectoring within the triangle or sequence slowed down. In these cases SM LIRF has to inquire into the cause of this behaviour and intervene with appropriate instructions to TN controllers if the root of the problem is the inappropriate separation of the traffic turned to the merge point.

It is interesting to notice that this issue came out during the third prototyping because of the effects of the wind. In fact many attempts have been carried out during the study before understanding that a separation of 6/7 NM within the triangle was necessary to have traffic with a separation of 3NM at the touchdown.
Nevertheless many different causes may imply an inappropriate separation within the triangle, in both runways configuration. As consequence, the strategy proposed has not to be considered targeted to runways 34L/R, as actually it is valid for the other runway configuration as well.

3.2.2 Use of PMS in case of low traffic load

In case of low traffic load the general PMS rule is to instruct the aircraft direct to the merge point as soon as it enters in the sequencing leg. In this case respecting the triangle capacity is not an issue (since it is respected by default) and most of the traffic is instructed direct to the merge point as soon as it enters in the sequencing leg. All the studies have confirmed the validity of this procedure.

During the first prototyping session the particular characteristics of the West triangle of Rome TMA allowed also to point out a possible modification of this method. According to this modification in case of low traffic load it may be effective to instruct the aircraft direct to the merge point even before it enters in the sequencing leg. The pre-requisite for the effective application of this additional method is that the aircraft is in the envelope area included in the prolongation of the triangle axes. The following Fig.9 shows in magenta what is intended by envelopes due to the prolongation of the triangle axes in Rome TMA operational scenario based on runways 16L/R.

The addition of the axes leads to the definition of triangles envelopes that exceed the triangles themselves. If the aircraft is within the envelope area it is possible to instruct it directly to the merge point before entering the sequencing leg. There is no reason for not shortening the flight path.

With RWY 16 L/R the triangles arrangement made this shortcut particularly useful on the West since most of the traffic to the West triangle comes from points that are included in the envelope area. In this case it was effective to apply the shortcut and there was no reason to wait for the aircraft entering in the sequencing leg to issue the direct to the merge point instruction. As a proof of the effectiveness of this method, during the study most of the traffic to runway 16R was managed in this way, receiving a direct to FRANK instruction when in the upstream sectors. The result was effective in terms of both:

- runway usage, since the separation was respected in both TN and AR sectors,
controllers workload, because the adoption of this method was considered a way to reduce the controllers workload in all SM LIRF, TNW and ARW positions, without at the same time increasing the controllers workload in the upstream sectors.

Fig.9 – The prolongation of the triangles axes implies the definition of envelope areas that exceed the triangles themselves (RWY 16L/R)

Conversely this shortcut revealed less applicable on the East because most of the incoming flows are from South-East and North-West, thus not included in the envelope area. Cases have been observed in which the controllers applied this
shortcut on the East with low traffic load. They found the strategy useful and effective in these cases, but its application is limited to the traffic coming from North-East (particularly from VELIM and KATAR).

With runways 34L/R the shortcut was appreciated as well. In this case it revealed more applicable on the East than on the West. In addition with this runway configuration two more issues have been observed that are worth to be reported in this document:

- on the East a violation of the rule has been often observed, according to which the traffic received the direct to merge point before entering the envelope. The result was the traffic following a path external to the envelope but quite close to the right side of the West triangle. No effects of this violation have been noticed on the effective application of the PMS method.

- traffic from South-East re-routed to the West triangle could easily intercept the localiser before joining the West triangle and reaching VANIA.

The following Fig.10 shows in green the envelopes created by the prolongation of the triangles axes when runways 34 L/R are in use. The dot line represents the violations described above.

The second violation – namely the localiser interception from the South - has not been observed during the study since the controllers have been instructed to follow the standard route and to insert the traffic into the sequencing leg. Their opinion was that the shortcut would have smoothed the traffic management without negative effects on the use of the PMS method.

It is interesting to notice that this use of the method opens a discussion on the effectiveness of using the point merge technique in low traffic load conditions.

At the beginning of the study PMS has been proposed as a technique to be applied in substitution of radar vectoring when the traffic load increases. Radar vectoring is then restored when the traffic load decreases. It is evident that this preliminary idea raises questions such as:

- which is the traffic threshold marking the need for a switch from radar vectoring to PMS and vice-versa?
• how to manage the switch between radar vectoring and PMS and vice-versa?
• who is responsible for instructing the switch?

The results of the study highlight that PMS can be applied effectively even in low traffic conditions with both runways configuration. As consequence in principle there is no need for switching from radar vectoring to PMS and vice versa depending on the traffic load. The PMS technique could be applied effectively also in case of low traffic load and the switch to radar vectoring could be considered as a recovery to be used in case of inapplicability of the PMS technique due to meteorological conditions (if

Fig.10 – The prolongation of the triangles axes implies the definition of envelope areas that exceed the triangles themselves (RWY 34L/R)
necessary, see par.3.2.7) or other causes.

The following paragraphs present the results produced during the study when trying to switch to conventional arrival management to PMS and vice versa. Both the experiences reinforce the idea to keep using PMS as standard method for arrival traffic management, independently from the traffic load.

3.2.3 Transition from conventional method to PMS and vice versa

The transition from conventional methods of arrival traffic management to PMS and vice versa has been investigated during the fourth prototyping session. Two scenarios have been implemented in order to analyse both the transitions. They focus on:

- transition to PMS in the morning due to forecast of traffic increase
- transition from PMS to conventional methods of arrival traffic management due to contingency

**Transition from conventional methods of arrival traffic management to PMS**

Scope of the exercise was to re-create a typical morning situation, with the traffic gradually increasing until the morning peak, and to define how to manage the transition from conventional methods of arrival traffic management to PMS. A briefing was arranged before the run in order to give the controllers information about the scenario and share with them the objective of the exercise.

During the exercise the controller acting as SM LIRF adopted a defensive strategy and decided to arrange the transition to PMS quite soon. This strategy was intended to make the transition as smooth as possible. Actually the results were very positive and the transition was managed in a very straightforward way.

After deciding to start the transition SM LRF informed the supervisor, all the controllers of the arrival sectors and the controllers of the adjacent sectors. The arrival controllers changed the maps on the radar screen, displaying triangles and point merges. As soon as passing to PMS they managed the traffic giving it direct to merge point instructions, as typical of low traffic load conditions. When the traffic increased they started using the sequencing legs and SM LIRF regulated the access to the triangles on the basis of the triangle capacity.
The process was very straightforward and simple and no penalisation has been observed in the traffic. However the controllers pointed out that this positive result was dependant on two possible risky activities, namely:

- a subjective decision of SM LIRF, who applied a defensive strategy and decide to start the transition process when the traffic load was still low
- a good coordination among the team members, with SM LIRF informing everybody and checking that every one was ready for the transition

If the transition were postponed or if SM LIRF was less keen on monitoring the others, it cannot be ensured that the same results would have been collected. These considerations enforced the controllers' opinion already mentioned in previous paragraph that it could be effective and safe to decide to use PMS as standard way of managing the arrival traffic instead of introducing it when the traffic increases.

This choice would allow to full profit by the method without leaving room to risks. It would seem particularly applicable when RWY 16L/R are in use. Conversely with RWY 34L/R more downwind is possible, thus making the controllers less convinced of the effectiveness of using PMS as standard method of arrival traffic management even in low traffic conditions.

**Transition from PMS to conventional methods of arrival traffic management**

The transition from PMS to conventional methods of arrival traffic management happened was tested in contingency. DME off were simulated so that a sudden reverse to conventional methods of arrival traffic management was necessary.

Also in this case the transition was managed in a very straightforward way. SM LIRF gave the information to TN controllers and SM LIRA. SM LIRA informed AR controllers. The controllers changed the maps in their radar screens in order to cancel triangles and point merges. Then they started radar vectoring the traffic. In their opinion the situation was very simple to manage in the AR positions, slightly more complex in the TN sectors where longitudinal and vertical separations had to be used.

It is interesting to notice that the execution of this scenario highlighted that the modification of the radar screen display was a key issue for the success of the transition. One of the controllers acting as AR did not change the map and presented
some problems of confusion in the management of the traffic since he was working
without the proper reference points. The controllers’ suggestion was to add a
functionality to quickly change the display (par. 3.6).

3.2.4 Use of PMS in case of go around

During the prototyping sessions several cases of go around have been simulated. The
management of these situations brought to the definition of two possible procedures to
be applied in case of go around. They concern the use of conventional radar vectoring
finalised to:

- traffic re-insertion into the sequence according to suitable available gap
- traffic re-insertion in the sequencing leg

Traffic re-insertion into the sequence in the triangle

In this case after the go around the AR sector controller radar vectors the aircraft in
order to re-insert it into the sequence already set in the triangle. Coordination among
SM, TN and AR sectors controllers is required in order to ensure the appropriate
spacing. All the sessions confirmed that this procedure is appropriate only in case
some spacing is already available in the sequence and/or minor adjustments are
sufficient to make it coherent with the spacing required for the traffic insertion. An error
in the identification of the hole or in its arrangement is likely to affect the whole traffic
management in the triangle, with evident negative results.

With RWY 16 L/R this procedure has been applied giving the aircraft a first clearance
of 6000ft and runway heading and then turning it in order to join the triangle. The
presence of traffic to LIRA implied a need for coordination between SM LIRF and SM
LIRA in order to avoid interferences, that otherwise was not necessary. In these cases
when the go around interested traffic from the East and was interfering with traffic to
LIRA, SM LIRF gave the aircraft 2 clearances instead of one. The first clearance was
to 3000ft and the second one to the final altitude coordinated with SM LIRA.

With RWY 34 L/R this procedure revealed applicable as well. Nevertheless the large
spacing required among the traffic due to the wind effect made it used less frequently.

All the studies have highlighted the need for giving SM LIRF the responsibility to
identify the spacing in the sequence where the aircraft will be re-inserted and to
communicate it to the other controllers. He can definitely take into considerations possible suggestions of SM LIRA or AR controllers. Anyway, it is up to him to make the final decision and communicate it to the others. This working method has the twofold purpose to share the knowledge within the team and foster the overall situational awareness. Many cases have been observed during the prototyping sessions in which SM LIRF left the decision to AR controllers. This choice created confusion in the go around management, change of the strategy on tactical basis, poor situational awareness and limited mutual understanding among the controllers. Conversely when SM LIRF has set the strategy of go around management, it has been handled in a smooth way, with good levels of cooperation and situational awareness among the controllers. This is the reason way this second strategy is worth to be preferred.

**Traffic re-insertion into the sequencing leg**

In this case after the go around the AR sector controller radar vectors the aircraft towards the sequencing leg. He then hands it over to TN sector controller who re-inserts it in the sequencing leg at a spare level.

Two limits have been envisaged in this strategy by the controllers involved in the first study and in the following ones. They concern respectively:

- fuel availability
- the need for making the aircraft climbing until the spare level and then descend again to the merge point

The highlight of these limits brought the controllers to prefer the first strategy considering it more effective than the second one in terms of both traffic management and controllers workload. Nonetheless they also highlighted that:

- the applicability of the first strategy may not be guaranteed in case of busy triangles
- the second strategy can be useful as standard procedure in case of go around with communication failure.

For this reason both strategy are considered valid and worth to be taken into account.

It is interesting to notice that in applying both procedures the controllers tended to
respect the aircraft provenance. This means that if the go around involved traffic from the East they tended to re-insert it into the East sequencing legs or triangle. Similarly if the aircraft was from the West they tended to re-insert it into the West sequencing legs or triangle. The third prototyping session has highlighted the possibility to use the other triangle, if it smoothes the go around management. This consideration came out from the observation that many go around interested the East triangle, that was at the moment quite busy, while the other was quite empty. As consequence the management of the go around was often quite penalising for the concerned aircraft.

Discussing this topic with the controllers they claimed that sending the aircraft originally coming from the East to the West triangle was not instinctive for them, also because of possible interferences with the current SIDs. But the topic is worth to be taken into consideration and further investigated because this procedure could smooth the traffic management.

3.2.5 Use of PMS in case of spacing increase

During the studies two different kinds of spacing increase have been simulated, with different traffic load and conditions. They referred respectively to cases of:

- request of spacing increase for runway inspection
- change of runway spacing

In the first case the tower requested the controllers to make a gap of 12NM for runway inspection. The nature of the inspection was mainly routine, thus there was some leeway for the controllers to react. Seldom instead the inspection was exceptional, meaning that the controllers had to promptly fulfil the tower’s request.

In the second case concerning the change of the runway spacing the tower informed the controllers that the landing spacing was going to be changed, whether immediately –due to contingency – or in a lapse of time to be coordinated with SM LIRF.

The studies produced positive results in all the conditions.

Even in high traffic load conditions the controllers fulfilled the requests in a very straightforward way and with low level of workload. This result has been confirmed even in single runway operations and in extreme – and for some aspects not fully
realistic – cases, in which in busy traffic conditions the separation on the East suddenly passed from 3 to 8NM or a separation of 12NM was requested for urgent inspection.

According to the controllers’ opinion, using the PMS method facilitates them in dealing with the request of spacing increase. Nevertheless for the successful management of these events it is important that a standard way of reacting to the request is applied. In other words, the introduction of the PMS method may make easier to satisfy the tower’s request, but the controllers need to have clear and precise rules to follow.

The rules defined during the studies are reported hereafter.

**Spacing increase for routine runway inspection**

In case the tower requests a spacing increase for routine runway inspection SM LIRF is responsible for fulfilling the request without at the same time penalising the traffic too much or affecting the smooth application of the PMS method. In general in dealing with the tower’s request his main tasks are the following:

- identifying the gap - it may be necessary to take some time before answering to the tower in order to consult with the other controllers
- communicating the gap to the tower
- communicating the need of spacing increase due to runway inspection and the gap identified to the other controllers concerned, giving precise indications on how to adjust the traffic if necessary
- monitoring the situation in order to be sure that the separation is respected

The controllers involved in the studies tended to consider the identification of the gap as the trickiest task of this process. Evidence has been collected that an error at this stage may affect the effective and smooth application of the PMS method. For this reason a few guidelines have been defined in order to standardise the controllers’ behaviour when dealing with this kind of situations as SM LIRF.

The preferable strategy to follow for not impacting too much on the traffic management is to profit by a natural hole in the sequence - if available. This choice ensures that the request can be fulfilled easily, with limited intervention on the traffic - just to adjust it in case the natural hole is not perfectly correspondent to the spacing
requested and needs to be slightly enlarged.

In alternative, if the triangle is busy and no natural gap is available, the preferable strategy to follow is to absorb the delay in the sequencing leg. This means that SM LIRF identifies the aircraft after which the inspection will be executed and let the following one navigating through the sequencing leg until the required spacing has been reached. The larger is the spacing requested by the tower, the more it is important for SM LIRF to choose as target one aircraft that can turn to the merge point as soon as entering into the sequencing leg. If so, the following one has the whole sequencing leg to absorb the delay and the risk to reach the end of the sequencing leg without being able to turn is limited. Nevertheless should it happen, the advisable strategy is to continue on the other sequencing leg at a spare level (par.3.2.1).

Some cases have been observed during the studies (particularly during the third one) in which this guideline revealed difficult to apply because letting the following aircraft navigating through the sequencing leg would have penalised the entire traffic flow. In these cases the controllers preferred to create the gap by removing one or more aircraft from the sequence and re-inserting it/them in the sequencing leg. This strategy was considered appropriate and acceptable for the effective use of the PMS method, provided that the traffic can be easily re-inserted in the sequencing leg.

**Spacing increase for urgent runway inspection**

In case of urgent runway inspection the tower communicates when the inspection has to be executed. This means that the tower communicates or coordinates with SM LIRF the target after or before which the requested spacing has to be ensured.

In these cases if the triangle is almost empty and the inspection profits by a natural gap in the sequence, SM LIRF just informs the other controllers of the runway inspection and monitors the situation in order to be sure that the gap is not absorbed.

On the contrary if the natural gap is not available, the preferable strategy to follow in order to fulfil the request is to remove one or more aircraft from the sequence and re-insert it/them in the sequencing leg.

**Increase of runway spacing**

In case of increase of the runway spacing SM LIRF is up to undertake different actions
depending on the traffic position with respect to the triangles.

Three phases have been identified, to which different actions have been associated.

- **In the triangle**

  if the increase of spacing is so urgent to apply even to the traffic already in the triangle - that is traffic that has already left the sequencing leg and is currently navigating towards the point merge – SM LIRF identifies the aircraft that does not comply with the required spacing, removes it from the triangle and arranges its re-insertion in the sequencing leg.

  This strategy has been considered the standard one and preferable. Other strategies have also been observed during the studies. They both foresee the use of conventional radar vectoring techniques: in one case with the purpose of sending the aircraft from the East to the West runway after the eastern point merge; in the other case with the purpose of increasing the spacing among the traffic. The controllers involved in the study considered the first strategy acceptable – provided that both tower and pilot have been previously informed of both runway change and radar vectoring and agreed on the new strategy. The second use of radar vectoring instead was considered unacceptable since likely to impact on the whole traffic management. Radar vectoring within the triangle is in fact likely to make TN and SM controllers not aware of AR controllers' behaviour and consequently uncertain on how to organise the other traffic.

- **In the sequencing leg**

  If the increase of spacing affects the traffic in the sequencing leg, the strategy to follow is to absorb the delay in the sequencing leg. This means that the traffic keeps on navigating through it until reaching the required separation from the previous one in the sequence. Traffic arriving at the end of the sequencing leg without being able to turn to the merge point has to be re-inserted it in the other sequencing leg at a spare level.

  The experience of the study revealed that this procedure may present some defects of applicability when RWY 34L/R are in use due the wind effect requiring large separations among the traffic in the east sequencing leg.
• **Outside triangles and sequencing legs**

SM LIRF evaluates the impact of the increased spacing on the triangle capacity and limits the access to it accordingly. Traffic exceeding the triangle capacity is re-routed to the other triangle and runway – if possible – or stopped at the holding points.

With respect to the last topic, the prototyping sessions have highlighted that the increase of the runway spacing may create some uncertainty to the controllers on the actual separation to apply when runways 34L/R are in use. As already mentioned in previous paragraphs in this case the wind value affected the aircraft performances on the East triangle, thus requiring an enlargement of the spacing in the triangle in order to reach the requested spacing on the ground. With standard separation of 3NM from touchdown, the experience of the simulation highlighted that a separation of 6/7NM was necessary within the east triangle. When the spacing increased to 8NM some attempts have been necessary before finding the appropriate separation in the triangle (finally set at 15NM). In the meantime the controllers had to cope with the inadequate spacing by means of radar vectoring techniques within the triangle or even in some cases removing the traffic from the sequence and re-insert it in the sequencing leg.

The observation of these cases brought to the consideration that a standard matrix could be useful, providing the controllers with indications on the separation to apply in the triangle depending on wind effects and separation requested from touchdown. It is worth pointing out that the separations suggested in the matrix should be approximate by excess, since the triangle conditions make easier for the controllers to reduce the separation among the traffic than increasing it.

**3.2.6 Use of PMS in case of runway change**

Many cases of runway change have been observed during the studies conducted so far. They have been mainly caused by:

- high traffic load in one of the two triangles
- problems of spacing in the triangle
- pilot’s request
- runway closure
In all these cases the runway change has been smooth and easy for the controllers, who appreciated the standard way in which all of them behave and the result produced in terms of effectiveness of the traffic management.

Detailed results concerning the four cases of runway change are provided hereafter.

**Runway change due to high traffic load in the triangle**

As discussed in paragraph 3.2.1 in high traffic load conditions the controllers tended to re-route the traffic to the other triangle and runway. Causes for re-routing were triangle capacity overload or high workload of the controllers (particularly those managing the East part of Roma TMA, because involved in the management of the traffic to LIRA).

In these cases SM LIRF tended to make the decision of runway change quite in advance, while planning the incoming traffic.

Discretional routings are available in the PMS operational scenarios to foster these cases of triangle and runway change. Despite the general working method recommending to link triangle and runway, all the prototyping sessions have highlighted a tendency to apply it mainly on the East.

Discretional routings have been generally used to re-route the traffic from the East to the West triangle. Conversely discretional routings from West to East have been rarely used, almost always associated to delay actions for the concerned aircraft that would have reached the point merge too early passing through the West triangle. The traffic from the West planned to land on the East runway tended to be managed in the West triangle and after the West point merge (FRANK or VANIA) to be cleared to the other runway profiting by the runways connection.

This shortcut had the twofold purpose to balance the workload between East and West TMA controllers and to avoid penalising the traffic. In some cases it has also been used in conjunction with the direct to merge point instruction before the entrance in the sequencing leg (par.3.2.2) in order to profit by natural gaps in the East sequence that elsewhere would have not been filled.

The shortcut of using the West triangle to manage traffic for the East runway was considered effective by the controllers involved in the studies and no negative or side effects of it have not been detected.
Runway change due to problems of spacing in the triangle

As discussed in paragraph 3.2.4 the management of urgent requests of spacing may require one aircraft to be removed from the sequence already set in the triangle. In this case the standard procedure is to re-insert the traffic in the sequencing leg. This procedure penalises the traffic quite a lot.

In order to avoid this penalisation the controllers can send the traffic to the other runway, if available.

This strategy profits by the runways connection if the traffic concerned has to go from the West to the East. On the contrary radar vectoring is necessary when the traffic is re-routed from East to West runway. In this case in fact no runways connection is foreseen and radar vectoring is the only means available. The application of this strategy requires the controllers to coordinate with both tower and pilot in order to ensure that they accept the runway change and the radar vectoring.

During the studies the controllers have often requested to add a connection from East to West runway to use in case of contingency – as for instance the spacing increase discussed in this paragraph. Actually in the original scenario the runway connection was intended to be used in single runway operation, when only the East runway is used. The possibility of using the West triangle to feed the East runway came out during the studies as additional working method.

The **recommendation** for the next stage of the project is to discuss the actual need for a runways connection from East to West, highlighting feasibility issues, possible drawbacks and cases in which it could be useful.

Runway change due to pilot's request

In general if the runway change is associated to a pilot's request the controllers have been observed to try as far as possible to fulfil it.

Due to the association between triangles and runways the pilot who wants a runway change has to make the request quite in advance, at least before entering the sequencing leg. In this case the request tends to be managed as described above, using the West triangle to feed the East runway and discretionary routings to send the traffic from the East requiring to land on the West runway to the West triangle. No problems have been detected as associated to this strategy, but for some difficulties in
distinguishing this traffic from the one following the conventional routings. The problem was mainly due to a usability defect of the label, that does not provide information about the runway on which the aircraft is planned to land. As described in par.3.6 during the studies the controllers tended to make up to this defect with the speed vector, but the results were sub-optimal due to the multiple and local use of it.

More complex than the case of early pilot’s request is the management of late pilot’s requests, made up when the aircraft is already in the sequencing leg. Various strategies have been tested during the studies to manage this particular situation. According to the controllers’ opinion the most appropriate and prudent one is to remove the aircraft from the triangle and re-insert it in the other sequencing leg. However since the procedure penalises quite a lot the aircraft, it is important to advise the pilot that it implies radar vectoring and a certain delay. Only after the pilot’s acknowledge the procedure can be applied. In most cases during the studies the pilot gave up the request of runway change, preferring to land on the other runway instead of on the requested one with a large delay.

**Runway change due to runway closure**

One case of runway closure has been simulated during the fourth prototyping session. It concerned RWY 34L and happened in a moment of quite dense traffic conditions. The results were not as positive as expected.

The controller acting as SM LIRF focused first on the traffic in the triangle, trying to identify where to insert the traffic from the West on the sequence for RWY 34R and how to harmonise the two traffic flows. Since the East triangle was quite busy he decided to use the sequencing legs to delay the traffic and merge the two traffic flows. Traffic not yet in the triangles has been stopped at the holding points.

Unfortunately the effort of SM LIRF did not reveal enough to prevent the use of extensive radar vectoring, particularly in the AR positions. This behaviour implied that TN controllers lose their reference points for the use of PMS and started radar vectoring the traffic as well. No reverse to PMS has been observed during the run.

This result presents some analogies with the first cases of go around managed during the study. Also in that case the controllers tended to minimise the penalisation, sharing it among the traffic, with negative results. Commenting the exercise during the
debriefing, the controllers admitted that for the effective execution of the scenario the most effective strategy would have been based on a penalisation of the traffic in the West triangle planned to land on RWY 34L. In their opinion a successful process would have been managed as follows:

- traffic in the west triangle already navigating towards the point merge is managed as a go around and reinserted in the sequencing leg of the most convenient triangle
- traffic in the east triangle is managed as planned, inserting traffic originally planned to RWY 34L in the sequence only in case of natural spacing available
- traffic in the west sequencing legs and planned to land on RWY 34L continues navigating through them until the traffic in the east sequencing legs has been managed; if necessary when arriving at the end of the sequencing leg it is reinserted in the other one
- all the traffic not yet in the sequencing legs stops at the holding point, until SM LIRF authorises it to proceed to the approach.

The principle on which this process is based is clearly the same used and found effective in case of go around. Extensive use of radar vectoring is to be avoided. Only the traffic directly interested by the event has to be penalised in order to keep using PMS effectively. This traffic is the one going around in one case and the one originally planned to land on the runway that has been closed in the other case.

### 3.2.7 Use of the PMS method in case of radio failure

Radio failure has been simulated in the second and third prototyping sessions. In both cases the radio failure happened on the East and concerned one aircraft just entered in the sequencing leg.

According to the PMS working methods, the procedure in this case foresees the pilot to fly the entire sequencing leg until the merge point, while the controllers plan and control the rest of the traffic accordingly.

The results of the studies revealed that using the PMS method the management of the radio failure was straightforward for the controllers and not critical at all. The main difficulty was to arrange the rest of the traffic in order not to interfere with the aircraft in
radio failure. In this respect three main aspects are worth to be reported, that impacted quite a lot on the traffic management in both the cases observed:

- the controllers presented evident uncertainty on the separation required after the radio failure
- they have been disappointed when realised that parallel independent approaches were occurring despite the radio failure
- SM LIRF pointed out poor involvement in the management of the radio failure

These common results brought to the conclusion that a standard behaviour is required even in case of exceptional circumstances as the radio failure. In particular:

- SM LIRF should be aware of the situation, because his involvement is a prerequisite for him to be able to appropriately coordinate with the tower and organise the traffic
- standard separation to be applied in case of radio failure should be defined
- parallel independent approaches should not be allowed in contingency

3.2.8 Use of PMS in case of bad weather and mixed equipped traffic

The controllers involved in the study often identified in the conditioned applicability of PMS in certain circumstances (i.e. bad weather conditions and mixed equipped traffic) one of its main drawbacks.

However it is interesting to notice that they tended to consider these drawbacks as acceptable. They tended to view these limits as a tolerable side effect of the method itself, definitely with rare probability to impair its acceptability or effectiveness.

This positive attitude was actually surprising. During the analysis of the first prototyping session this result has been partially justified considering that the controllers involved in study had not the chance to face these drawbacks and could just discuss about them on a purely theoretical way. This lack of direct experience was considered in short a possible factor influencing the controllers’ opinion on the acceptability of the drawbacks themselves. For this reason the report contains a recommendation for the next prototyping sessions to simulate cases of mixed equipped traffic and bad weather conditions. This suggestion has the twofold purpose
to evaluate the actual impact of these conditions on the use of the PMS method and to check the results of the first prototyping session about the acceptability of the drawbacks of the method.

Following this advice bad weather has been simulated in both second and third prototyping sessions, while cases of mixed equipped traffic have been simulated during the fourth prototyping session.

The results were in both cases coherent with those collected during the first prototyping sessions. MSP confirmed to be not fully applicable in these cases, but this limit was not considered as impairing its effectiveness or acceptability. In case of mixed equipped traffic the controllers did not found problems in radar vectoring some aircraft while at the same time managing the rest by means of PMS. In case of bad weather they claimed to consider PMS as a support, even if used in a non standard way or partially. Details on the way the two scenarios have been managed are provided hereafter.

**MSP in case of bad weather**

Bad weather has been simulated in the East triangle, in both runways configurations. At the beginning of the exercise the supervisor informed the controllers about possible bad weather to the East, not yet impacting on the arrival traffic management in Rome TMA. After a while some arrival traffic reported bad weather and asked to avoid it.

The bad weather was planned to expand over the East triangle, from about FL90 up. This means it was not planned to affect the West triangle and point merge. The way the bad weather has been implemented was intended to allow the controllers to decide whether to keep using the PMS method -even though in non standard way- or instead than reverting tout court to radar vectoring. In both cases they have opted for the first strategy, since just the possibility to use the triangle or just the point merge was considered of great support for them.

The controllers’ reaction to the bad weather was different in the two cases.

During the second prototyping session, based on **runway configuration 16L/R**, SM LIRF initially stopped the traffic in holding before the entrance to the East triangle. He then decided to converge all the traffic destination LIRF to the West triangle. Not all the traffic however was planned to land on the west runway. The traffic was balanced
on the two runways, since the tower accepted SM LIRF’s request to temporary reduce to 3NM the spacing required on RWY 16R. All the traffic was managed in the West triangle making couples of traffic to RWY 16R and 16L, flying the sequencing leg vertically separated. TNW gave the direct to instruction to the aircraft of each couple almost at the same time and then instructed them the descent to two different flight levels: 5000ft to the traffic going to FRANK and landing on RWY 16R, 6000ft to the traffic going to STAIR and landing on RWY 16L. He then handed over the traffic to ARW, who managed the couples flying vertically separated within the triangle. After FRANK, ARW cleared the aircraft for RWY 16L to further descend to 4000ft and handed it over to ARE. ARE managed the final part of the sequence to RWY 16L and supported TNE in dealing with traffic to LIRA whose management was affected by the bad weather conditions.

This strategy revealed effective. The traffic was managed in a smooth way and no large delays have been recorded. Nevertheless two main limits have been noticed.

The first limit concerns the distinction of traffic to RWY 16L and 16R. As all the traffic entered the west sequencing legs at standard levels and the label did not provide indication of the runway (par. 3.6), TNW had some troubles in distinguishing traffic to the two runways. He used the speed vector but it was not effective enough. Also the support of SM LIRF revealed unfit for this task since many cases have been observed in which SM LIRF was confused and did not remember the traffic distribution on the runways.

The other limit highlighted during the application of this strategy concerns the tasks distribution among the AR controllers and their cooperation. In the particular case observed during the study the controllers workload remained at acceptable levels. Nevertheless the workload distribution among ARW and ARE was clearly unbalanced. Since all the traffic to LIRF was managed in the West triangle ARW was very busy. The same level of workload was not perceived by ARE who merely managed the final part of the sequence to RWY 16L (from FRANK to the runway) and supported TNE in dealing with traffic to LIRA. This unbalanced level of workload impacted on their cooperation since ARW was so busy to have difficulties in communicating with ARE. As consequence the two controllers appeared quite independent and with a poor mutual awareness.
During the third prototyping session, based on runway configuration 34L/R, SM LIRF opted for a mixed mode solution.

The solution adopted in the second prototyping session was in this case less applicable since the triangles configuration did not allow to easily re-route the traffic from the East to the West triangle. This strategy has been applied for some aircraft, mainly from the South, that could easily follow the discrentional routing. It would have instead implied a long re-routing in case of traffic from East. As consequence this traffic has been managed by means of conventional radar vectoring technique, having as point of reference the point merge SHARA. This means that TNE kept making the sequence on SHARA but did it using radar vectoring instead of sequencing legs, triangles and distance rings. Of course the adoption of radar vectoring for bad weather avoidance did not allow to have a sequence in which each traffic was 5NM from the previous one and to the next one. In some case radar vectoring to the west runway have been necessary since two aircraft were too close to land on runway 34R. Nevertheless since most of the traffic tended to fly in a corridor external to the triangle the situation appeared very ordered and calm.

**MSP in case of mixed equipped traffic**

In case of mixed equipped traffic the traffic not PRNAV equipped has been radar vectored according to the conventional method of arrival traffic management. The controllers did not find it difficult, nor risky. The only aspect remarked as important to take into consideration is the need for keeping SM LIRF informed about the traffic not PRNAV equipped and about the way it will be managed. This is a key aspect for allowing him to properly organise the traffic in the triangles.

**3.2.9 Flexible use of the PMS method**

Concerning the flexible use of the method the results of the second and third prototyping sessions have completely confirmed what already came out during the first study.

The controllers involved in all the studies have often highlighted that introducing the PMS method may imply a certain loss of flexibility with respect to the open loop vectors currently used (par. 3.1). Nonetheless this loss of flexibility has been considered acceptable because counterbalanced by evident benefits in terms of
workload reduction and efficiency of the arrival traffic management.

In addition one other reason contributed to make the method acceptable and domain suitable for the controllers. It was the possibility of a flexible use of the method.

In the previous paragraphs, the effectiveness of the PMS method has been described as strictly dependent on the application of its basic principles, namely:

- the pre-sequencing according to which the upstream sectors hand the traffic over to TMA sectors with a spacing of at least 7NM, steady and at predefined speed and flight level,
- the use of first in first out principle and distance ring while the aircraft is in the triangle
- the association between triangle and runway (but for cases of pilot’s request and runway balancing)
- the use of triangles capacity, segments of the sequencing leg and triangles as trigger for SM LIRF intervention (whose need came out during the study).

In general the respect of these rules guarantees the successful application of the method. Nonetheless it may also happen that these rules are violated. In these cases all the prototyping sessions have revealed that the method can be quite flexible.

Some cases have been observed during the prototyping sessions in which the method has been successfully applied notwithstanding violations in the application of its basic rules. In particular these cases concerned:

- **violation of the pre-sequencing rule**

  Two different cases of inappropriate pre-sequencing have been observed during the study.

  In the first case 2 aircraft have been handed over to TN sector one above the other, meaning that they entered in the sequencing leg at the same time and on the same point, but at different flight levels. TN controller managed the situation in two steps. He quite soon instructed the first aircraft (that was steady at the pre-defined flight level) to turn to the merge point and then to descend. He left the other one continuing to descend to the flight level of the sequencing leg while flying through it. When the first aircraft reached the distance ring, he
cleared the other aircraft direct to merge point instruction and then descent.

In the second case the inappropriate pre-sequencing affected most of the inbound traffic to LIRF, since it was due to bad weather in the upstream sectors. Also in this case the controllers continued managing the traffic with PMS, using the sequencing leg to appropriately sequence the traffic. They found the method comfortable and reliable. They also claimed that the key element for the effective application of such flexible use of the sequencing leg was the respect of the triangle capacity (par.3.2.1).

- **violation of the first in first out rule**

  In this case two aircraft entered opportunely pre-sequenced in the sequencing leg. Since the first one was Heavy, the TN sector controller decided to violate the first in first out rule. As consequence he gave the direct to merge point instruction to the second aircraft first and then to the other in order to profit by a hole in the sequence.

- **violation of the association between triangle and runway**

  In this case SM LIRF coordinated with the upstream sector controller that one traffic coming from North-West and expected to land on East runway was managed within the West triangle and then, after FRANK/VANIA sent to East runway. The upstream sector controller managed it accordingly, handing it over to the TN sector controller opportunely separated from traffic to the West runway. The TN sector controller, knowing that the two aircraft were expected to land in two different runways, and in agreement with the SM LIRF, gave the direct to instruction to the two aircraft almost at the same time. He then instructed them the descent to two different flight levels: 5000 to the aircraft landing on the West and 6000 to the other one. He then instructed this latter to further descend to 4000ft after the point merge.

- **Vectoring inside the triangles**

  In this case some aircraft have been radar vectored inside the triangles, while flying from one distance ring to the other in order to adjust the sequence or to create the spacing for a go around to be inserted. Similarly other flights have been slightly vectored in the final path for spacing or to be re-routed to the
West runway – in exceptional cases.

- **Violation of triangles capacity**

  In this case due to external events (namely go around or runway inspection) the triangle revealed temporary overloaded and some aircraft arrived at the end of the sequencing leg. The TN sector controller radar vectored the traffic, as extending the sequencing leg, and then re-inserted them into its part direct to the merge point.

  It is interesting to notice that these violations have not been perceived as problematic. On the contrary the controllers tended to consider these cases as a proof of the possibility to use the method in a flexible way when necessary. It was considered an advantage of the technique, that though rigid allows to violate its own rules if necessary and in sporadic cases, well coordinated with SM LIRF. What is interesting to notice is that these violations were considered effective if applied in exceptional situations and well coordinated internally to the team. Conversely they were considered likely to compromise the effectiveness of the method if applied in a systematic way and without coordination with the rest of the team.

  The **recommendation** for the next stage of the project is to include this topic in the training package, clearly highlighting that the method is rigid but seldom can be used in a flexible way if necessary. Systematic violations are not allowed since they are affecting the effectiveness of the method itself.
3.3 Appropriateness of roles and working methods

Roles and working methods applied proposed at the beginning of the study were based on the following principles:

- the upstream sectors controllers (collected in one feeder position during the prototyping sessions) pre-sequence the arrival traffic at a minimum distance of 7NM and hand it over to TN sector controllers at a pre-defined flight level and speed (both conditions reached at least 10NM before the sequencing leg)
- TN sector controllers manage the aircraft entrance into the sequencing legs and the navigation through the sequencing legs until the instruction to the merge point
- AR sector controllers adjust the sequence with speed reductions
- SM LIRF coordinates with upstream sectors and SM LIRA, passes relevant information to TNE and ARE controllers and manages the runway balancing if necessary
- SM LIRA coordinates with LIRA TWR and SM LIRF, and passes relevant information to TNE and ARE controllers. He is moreover responsible for the sequence to LIRA.

These roles and working methods revealed effective and appropriate. The controllers’ opinion was that though requiring some adjustments, they are basically adequate for the effective application of the PMS method and also acceptable and suitable to be used in Rome TMA. This high acceptability largely depends on the choice of maintaining continuity with the current roles and working methods applied in Rome TMA. This choice revealed successful and contributed to make the controllers well-disposed towards the new method of arrival management, considering it as an evolution of the current one.

The adjustments required mainly concerned the use of these working methods.

Several cases have been observed in all the studies in which the workload tolerance of one controller or conversely the defensive attitude of another one have brought to unsuccessful results in terms of effective application of the method and consequently of smooth arrival traffic management. Good results have been instead obtained when
everybody played his own role according to predefined and precise rules, allowing the others to have correct expectations on which planning their own work.

These considerations convinced the controllers of the need to apply these working methods in a quite rigid way and to identify in the standardisation of the controllers’ performances a pre-requisite for the effective application of the PMS method. The standardisation ensures in fact mutual awareness, teamwork among the controllers and most of all predictability of the controllers’ behaviour.

The application of this requirement implies a radical cultural change in the TMA controllers, currently used to be proud of their creativity and workload tolerance while managing the arrival traffic. At present this cultural change foreshadows as the real challenge for the application and acceptance of the method.

The recommendation for the next stage of the project is to take into consideration the importance of the standardisation of the controllers’ performances for the successful application of the method, and to point out at the same time the effort that this change implies at cultural level.

In the following there is a presentation of the detailed results of the prototyping sessions concerning roles and working methods of SM LIRF, SM LIRA, TN and AR sector controllers. These results have been structured per role in order to facilitate the presentation of the results. The last part concerns the use of the method in single runway operations.

**Role and working methods of SM LIRF and SM LIRA**

During the study SM LIRF played a key role for the effective application of PMS. He was considered a master coordinator and confirmed to be the heart of the configuration, both in single runway and in full runways operational scenarios.

With low traffic load his role was quite marginal, since the controllers managed the traffic in a straightforward way according to the PMS method. His role was instead more decisive and strategic for the effective management of the arrival traffic, when the traffic increased and/or in case of particular events. In these cases in fact he was responsible for:

- setting the strategy, deciding whether to apply runway balancing and/or to use
the holding,

- coordinating the application of this strategy with the adjacent sectors.

The new rules defined during the various studies based on triangles capacity and use of sequencing leg and triangle (par. 3.2.1) supported him in this task. In fact organising the traffic on the basis of more objective and standardised criteria of traffic management implies the effects of:

- standardising the SM LIRF behaviour
- increasing the teamwork in the TMA positions thanks to the possible anticipation of SM LIRF behaviour

The two effects are strictly interconnected. Since the SM LIRF tends to behave in a standard way, applying the basic principles of the PMS method, TMA sectors controllers are able to anticipate his behaviour and vice versa. This anticipation has been observed to increase the teamwork and reduce the controllers’ workload, as everybody had correct expectations on the others’ behaviour, could organise his own work accordingly and had limited need for internal explicit coordination.

This ability of understanding and anticipating the other controllers’ behaviour is expected to have positive effects on safety, since introduces mutual control and redundancy. Nevertheless also a side effect has been observed. Knowing and understanding the SM LIRF’s work brought sometimes the TMA sectors controllers to bring their own decision forward, objecting on the effectiveness of the strategies proposed by SM LIRF.

This kind of over-control, considered superfluous and ineffective, was quite evident during the first prototyping session and required to often remark the role of SM LIRF and the need for the others to comply with the strategy set. Considering the experience of the first prototyping session and the recommendation that it produced, in the training of the following sessions the concept of SM LIRF predominance has been stressed, with evident positive results during the studies. Very few cases of redundancy have been observed after that. Conversely, knowing the SM LIRF role and understanding the reasons of his predominance, the other controllers tended to apply a proactive behaviour, providing him with suggestions that he then was free to evaluate and further accept or reject in the light of his broad view of the traffic.
The **recommendation** for the next stage of the project is to stress the concept of SM LIRF predominance during the training.

It is worth underlining that during the first prototyping session a similar phenomenon of redundancy has been often observed between SM LIRF and SM LIRA. The controller playing this latter role often tended to substitute to the first one in his key tasks (i.e. runway balancing) with the results of:

- increasing the phone communication between the two
- partially failing his role of mediation between TNE and ARE

This problem has been solved during the study remarking the strategic role of the SM LIRF with respect to SM LIRA and slightly changing their working methods. The modification introduced mainly consisted in making SM LIRA responsible for passing the information received from SM LIRF not only to TNE and ARE but also to ARW. In that case the modification revealed effective and both problems of ARW awareness and redundancy between SM LIRF and SM LIRA have been solved.

Following the recommendation of the first prototyping session, during the second and the third prototyping sessions this modification has not been applied in order to evaluate the effect of the addition of traffic to LIRA on the redundancy between the two roles. The studies revealed that the addition of traffic to LIRA largely contributed to limit the redundancy, particularly during the third prototyping session and in full runway configuration cooperation.

Nevertheless the same problem of information exchange noticed during the first prototyping session tended to be confirmed. In general no problems have been noticed when the information goes from AR controllers to the others (for instance in case of go around). Conversely the communication was less immediate and effective when goes from TN controllers or SMs to the others. Many cases have been recorded in which ARW has not received the information in time or even at all.

The cause of this problem has been identified in the working methods adopted, particularly those of SM LIRF.

According to the working methods, SM LIRF is responsible for setting the strategy and communicating relevant information and instructions to the other controllers. This
communication is supposed to be direct with TNW and ARW controllers, while mediated by SM LIRA with TNE and ARE controllers.

Confirming what already noticed during the first prototyping session, both the studies highlighted that while working as SM LIRF the controllers tended to forget to pass information to ARW controller. The communication was instead straightforward and often tacit with TNW controller. In some cases, particularly in single runway operation, the mediation of SM LIRA in passing the information from SM LIRF to TNE and vice versa was considered a bottleneck of the process.

In order to solve the problem a modification has been introduced and tested during the third prototyping session, according to which was the AR controller who first received the information in charge to pass it to the other. This solution, though improving the process, was however not perfect. On the basis of this consideration at the end of the third prototyping session another solution has been proposed to solve this problem. It is quite similar to the one suggested during the first prototyping session and consists in giving:

- SM LIRF the task to communicate with both TN controllers and SM LIRA
- SM LIRA the task to communicate with both AR controllers and SM LIRF

This new working method revealed effective during the fourth prototyping session, in which the process resulted speeded up and more efficient. SM LIRF was able to easily communicate with both TN controllers, while SM LIRA ensured that both AR controllers were aware of relevant situations and/or instructions. The application of this working method required changes in the room layout that are described in par.3.5.

**Role and working methods of TNW/TNE and ARW/ARE**

During the prototyping sessions TN and AR controllers applied the standard working methods associated to PMS.

According to these working methods each TN sector controller instructs the aircraft to turn to the merge point, after appreciating the turn instructs it to descend (to the merge point or to the intermediate step depending on the operational scenario) and hands it over to AR sector controller. AR controller manages the aircraft descent in the triangle, adjusting its speed in order to keep the separation required.
These working methods confirmed to be effective and applicable. The addition of radar minima constraints did not affect the appropriateness of the working methods and was not perceived by the controllers as a relevant factor of workload increase.

A few problems have been noticed during the studies due to the fact that all TN and AR controllers often tended to forget to update the system with the clearances (i.e. speed or routing) given to the traffic. When reasoning about this behaviour the controllers tended to mark it as heritage of the current work in the control room, where paper strips are still used to manage the arrival traffic. The same argument has been used to explain the problem of communication flow described in previous paragraph. Updating the paper strip and sharing it with the colleagues is a means to ensure mutual knowledge and situational awareness.

During the studies the controllers tended to count on the same mutual and situational awareness without considering that paper strips ensuring it were not available. As a consequence problems of mutual and situational awareness have been pointed out, with consequent increase of phone communications among the TMA controllers. System update and verbal communication among the controllers revealed then crucial for the success of the work.

The **recommendation** for the next stage of the project is to stress the need of system update for the effective application of the method. The system update is moreover a pre-requisite for the use of AMAN.

**Roles and working methods in single runway operations**

Applying the PMS method in single runway operations confirmed to be much more complex than with full runway configuration. The difficulty was associated to the definition of the arrival sequence that was less straightforward and evident than when each triangle is almost univocally associated to one runway.

The operational configuration used during the study was based on 5 working positions, namely TNW, SM LIRF, AR, SM LIRA and TNE. In this configuration each TN sector controller was responsible for managing the traffic in the sequencing legs according to the sequence arranged by SM LIRF. The final part of the sequence was managed by the AR controller, who also managed the traffic inbound to LIRA.

The application of these working methods produced positive results, highlighting the
effectiveness of using two triangles to feed one runway. In particular the following requirements have been elicited:

- **Build the sequence on the basis of pre-defined and well known principles**
  
The standard PMS principle FIFO has proven to be effective to make all the controllers aware of the sequence. A further principle has also been added during the study considering whether the traffic is entering in the internal or in the external sequencing leg. According to this principle, named Inner Outer (IO), in case of two aircraft entering two different sequencing legs at the same time it is preferable to serve first the one in the inner sequencing leg. The use of these principles fostered the cooperation among the team, contributed to make the two SMs sharing the same view of the sequence and most of all to reduce the need for verbal communication.

- **Have a director of the traffic sequencing, able to deviate from standard principles if necessary**
  
On the basis of the positive results got during the study applying the standard FIFO and IO principles, a test has been arranged consisting in allowing TN controllers to build the sequence on their own. Purpose of the test was to investigate whether these principles are sufficient for the effective application of the method in single runway operations. The results were negative. These principles resulted important for the teamwork, as they introduce a common view of the sequence once the traffic is in the sequencing leg. The traffic arrangement before the entrance to the sequencing leg and the management of not perfectly standard situations require however the work of a director.

- **Consider the wind effects on traffic performances**
  
With RWY 34R/L the traffic management has been deeply conditioned by the effects of the wind. As effect of the wind the traffic in the same triangle tended to have different performances, since the one from the North was faster than the one from the South. These different performances of the traffic affected the feasibility of basing the arrangement of the sequence on the PMS principles – FIFO and IO – that revealed effective with RWY 16L/R. In this case in fact the traffic from the South tended to have an advance on the traffic from the North.
As consequence of the heterogeneous traffic and of the lack of pre-defined and shared principles, the sequence was less standard and univocal than in the previous cases, with evident consequences in terms of mutual and situational awareness, teamwork and communication. Several cases of misunderstanding and redundancy have been noticed during the third prototyping session between SM LIRF and SM LIRA, mainly due to the lack of a common view of the sequence. The problem was caused by the working methods and room layout adopted. In the fourth prototyping session in fact the same problem has not been noticed since changes have been introduced in order to allow SM LIRF to communicate directly with both TN controllers, without any need for the intermediation of SM LIRA. A further improvement is expected as result of the modification of the system HMI allowing SM LIRF to show and update the sequence in the radar screens of the TMA controllers (par.3.5).

- **Allow a flexible management of traffic to LIRA**

  The study revealed that with dense traffic load AR controller may be overloaded by the need to manage both traffic to LIRF in the triangle and traffic to LIRA, by means of conventional techniques. Some cases have been observed in which the management of traffic to LIRA distracted AR from the sequence to LIRF or vice versa. In order to avoid this problem the working methods have been slightly changed during the study in order to allow:

  - TNE controller to manage traffic to LIRA at least until setting the sequence
  - SM LIRF to balance the traffic in the triangles in order to avoid to overload TNE

  This new working method revealed effective during the study. For TNE managing the traffic to LIRA was not a problem, particularly if the amount of traffic in the east triangle was limited by SM LIRF on the basis of the triangle capacity. AR could focus on the last part of the sequence to LIRF and also to LIRA, this latter if possible. The coordination between AR and TNE is essential for the success of the traffic management. Cases have been observed in which after a proper coordination the sequence to LIRA has been completely
managed by TNE, with positive outcomes in terms of both traffic management and workload distribution among the controllers. Other cases have also been observed in which the traffic was completely managed by TNE, but without previously coordinating with AR. In these cases the results were not positive, since AR tended to lose situational awareness. The controllers suggested to extend this modification also to the working methods applied with full runways configuration.

The final agreement was to:

- give TNE/W the responsibility to manage the first part of the sequence to LIRA, until interesting the flight levels of the sequencing legs
- give ARE/W or AR (in case of single runway operations) the responsibility to manage the last part of the sequence to LIRA whose traffic is at flight levels below the sequencing legs
- allow a flexible allocation of the traffic to LIRA between TNE/W and ARE/W (or AR), on the basis of their respective workload.
3.4  **Impact on controllers’ workload**

The following graphs show the workload perceived by the controllers during the prototyping sessions. Data have been extracted from the post-exercise questionnaire that the controllers have filled in at the end of each run.

**Fig.11** – The workload perceived during the first prototyping session in both single runway and full runways configurations and with different traffic loads

**Fig.12** – The workload perceived during the second prototyping session in both single runway and full runways configurations and with different traffic loads
Confirming the results of the first prototyping session all the graphs point out the complexity of managing the single runway scenario. The workload perceived in single runway operations is higher than the one perceived in full runways configuration. The result of this comparison is particularly interesting considering that the exercises used in single runway operations were characterised by 40 aircraft/hour to LIRF plus 8 aircraft/hour to LIRA (but for prototyping session 1). This density slightly exceeds the maximum capacity in single runway operations (currently set at 37 + 11 aircraft/hour).
A lower level of workload was perceived in both cases with full runways configuration, even with a density of 60 + 13 aircraft/hour, that largely exceeds the maximum capacity of this operational scenario (currently set at 54 + 11 aircraft/hour).

Looking at the results gathered in single runway operation it is evident that in the third prototyping session all the controllers tended to perceived a higher workload than in the other prototyping sessions. This difference from the previous two was mainly due to the wind effect. As effect of the wind in fact traffic from North and South tended to have heterogeneous performances, thus impairing the controllers from applying the standard PMS principles First In First Out and Inner Outer. The lack of standard principles implied two main consequences: redundancy among the controllers and increase of coordinations. These factors are considered the main cause of workload increase. In the fourth prototyping session the positive effect of the revised working methods and room layout can instead be noticed. The wind effect continued to be present but its impact on controllers’ workload was definitely lower since the new working methods and room layout made the coordination easier and faster.

A further aspect that is interesting to discuss comes out from the comparison of the workload perceived in single runway operations during the first and the second prototyping sessions, based on the same operational scenario.

It is evident that the results of the two graphs are mostly coherent, but for SM LIRF workload that in the second prototyping session was quite lower than in the first prototyping session. This difference has been explained as the combined effect of two factors:

- the introduction of the Inner Outer principle
- the reduction of the redundancy with SM LIRA, that largely impacted on SM LIRF’s workload during the first session

In the graph of the second prototyping session SM LIRA’s workload is still high but this is considered partially due no more to the redundancy with SM LIRF, rather to the management of traffic to LIRA and to the need to pass the SM LIRF’s instructions to TNE and ARE controllers.

The graphs offer also some other insights concerning the application of the PMS method in full runways configuration.
A first aspect to be noticed concerns the confirmation of what already discussed about the SM LIRF, whose role tends to be decisive and consequently demanding as soon as the traffic load increases. In the graphs his workload is quite low with low traffic load, in some cases less than the one perceived in the other positions. When the traffic load increases his workload increases as well.

A second aspect of interest is the confirmation of what noticed about the single runway operations. In general the third prototyping session presents levels of workload that are higher than those of the other prototyping sessions. This result has been mainly attributed to the wind, that largely affected the aircraft performances during the study. This effect is particular evident in the workload perceived in TNE and ARE positions that tends to be quite high as soon as the traffic load increases. This tendency is due in the TNE position to the need to manage the traffic in order to ensure the large separation requested in the triangle and in the ARE position to the need to maintain the separation and to manage at the same time the traffic to LIRA. In the fourth prototyping session the effect of the wind on the controllers’ workload was minor since the new working methods and room layout allowed them to coordinate more easily and quickly.

Finally a last interesting aspect to be noticed concerns the low level of workload associated to all the positions even in very high traffic loads (equal to or exceeding the maximum runways capacity). This result confirms what often reported by the controllers during the debriefings, namely the extreme simplicity of managing the arrival traffic with this method even in particular cases of high traffic density, go around and runway inspection.
3.5 ** Appropriateness of the simulation room layout**

As presented in par. 1.5, the simulation room layout adopted was based on 6 controller working positions, namely TNW, TNE, ARW, ARE, SM LIRF and SM LIRA. During the first three prototyping sessions they were arranged in the following order: TNW, SM LIRF, ARW, ARE, SM LIRA and TNE. The working positions were coupled according to the real operative room layout constraints. As consequence the simulation working environment was based on the following room layout (fig. 14 and 15).

![Fig.14 – the simulation room layout in full runways configuration](image1)

![Fig.15 – the simulation room layout in single runway configuration](image2)

During the first three prototyping sessions this simulation room layout revealed not perfectly suitable for the application of the PMS method in Rome TMA. It presented problems of information exchange that were partially dependant on defects in the working methods (par.3.3) and partially contributed to them.

The main problems detected during the prototyping session were the following:

- the physical separation between SM LIRA and SM LIRF implied the need for phone coordination between the two and contributed to the redundancy of SM LIRA with respect of SM LIRF (that has been noticed in the particular during the first prototyping session)
• the physical separation between SMs and ARs often resulted in a better cooperation between SM and TN than between SM and AR, with consequent problems of situational awareness for AR sectors controllers due to the lack of information provided by the SMs

• the physical separation between SM LIRF and TNE revealed ineffective - specially in single runway operations- since SM LRF had difficulties in communicating the sequence to TNE through the mediation of SM LIRA.

Several alternative layouts have been envisaged during the studies in order to solve these problems and partially to comply with the modifications introduced in the working methods of SM LIRF and SM LIRA (par.3.3). At the end of the third prototyping session it was decided to use the forth prototyping session to test the following alternative layout.

![Diagram](image1)

**Fig.16 – alternative simulation room layout in full runways configuration**

![Diagram](image2)

**Fig.17 – alternative simulation room layout in single runway configuration**

This alternative layout is associated to a change of the working methods (par.3.3) according to which SM LIRF is responsible for coordinating with TN controllers, while SM LIRA is in charge of the coordination with AR controllers.

The introduction of the alternative simulation room layout, together with the revised working methods, produced extremely positive results during the fourth prototyping session. In particular it has been observed to:
• definitely smooth the process of coordination between SM LIRF and TN controllers in both single runway and full runway configurations
• increase the mutual and situational awareness in all the working positions
• avoid problems of redundancy between SM LIRF and SM LIRA in both single runway and full runway configurations
• avoid problems of ARW isolation noticed during the first three prototyping sessions

It is however worth highlighting that the alternative layout tested during the forth prototyping session presents one limit. In order to allow SM LIRA to easily coordinate the management of traffic to LIRA with both ARE and TNE, the positions of ARE and ARW have been reverted with respect to the geographical orientation of their sectors. In other words ARE is on the left, while ARW is on the right. This limit has been observed to imply a certain confusion for SM LIRA, SM LIRF and TN controllers, particularly in busy periods or urgent or contingency situations. It was instinctive in these cases to consider ARE as the one sitting on the right and ARW the one sitting on the left. No particular problems have been noticed during the study as due to this limit of the room layout. Nevertheless it is important to consider that this could be a possible cause of confusion and misunderstandings for the controllers. Such risk can be however considerably reduced with an appropriate training and a suitable familiarization of the users.

During the analysis an alternative layout has been envisaged in order to cope with this limit and solve the possible problems it may cause. It consists in changing the physical orientation of the controllers working positions, though maintaining the order tested in the fourth prototyping session.

The solution proposed is depicted in fig. 18. It represents the full configuration when both runways are in operation. In single runway operations the ARW position is supposed to be collapsed into a single AR position.

In this configuration a semi-circular horseshoe bay holds the controllers working positions, that are in the same order applied in the forth prototyping session, namely TNW, SM LIRF, TNE, SM LIRA, ARE and ARW.

The horseshoe configuration may reduce the risk of confusion since looking at the AR
positions from TNs or SMs positions ARW is actually on the left of ARE. Moreover this configuration may facilitate the communication between TN and AR controllers.

This layout has not been discussed with the controllers involved in the prototyping sessions. The **recommendation** for the next stage of the project is to test or at least discuss it with the controllers in order to evaluate whether it is actually able to solve the problem of confusion and misunderstanding experienced with the layout applied in the fourth prototyping session.
3.6 Appropriateness of Human Machine Interaction

The system used during the prototyping sessions revealed almost effective for the application of the PMS method. The absence of STCA and MSP was not perceived as problematic.

A few defects have however been detected during the studies. They have been divided in two classes concerning:

- the lack of some information considered necessary for the effective application of the method and the smooth management of the arrival traffic
- the lack of some functionalities of display setting that are considered important to allow the controllers to properly apply the method.

Details are provided hereafter.

3.6.1 Defects of missing information

Problems of missing information concern:

- the assigned speed
- the assigned runway
- the arrival sequence

The lack of each of these pieces of information implied inquiries by the controllers and brought to ineffective behaviours.

**Lack of information about the assigned speed**

The label provides only information about the actual speed. The controllers’ opinion is that the assigned speed is also important to manage the arrival traffic. The lack of this information implies problems of situational awareness and induces the controllers to often check the assigned speed with the pilots.

This problem could be easily solved just adding this information in the label and allowing the controllers to update it according to the instructions provided.

**Lack of information about the assigned runway**

One of the basic principles of the PMS method is the association between aircraft
bearing, triangles and runways. According to this principle the direction from which the aircraft comes determines the triangle in which it is inserted and the triangle in turn determines the runway. This principle is quite straightforward and effective.

Problems of situational awareness have been noticed during the study when this principle has not been respected due to runway balancing or requests of runway change. In these cases in fact the bearing is no more a sufficient indicator of the runway in which the aircraft will land.

During the studies the controllers have often been observed to use the speed vector to mark the aircraft not respecting the principle above. This behaviour was useful for the controllers. Nevertheless it is not effective. It presents in fact two main problems:

- it marks in the same way different kinds of traffic, as for instance traffic that have been rerouted from the other triangle to the one managed and traffic managed within the West triangle but is supposed to land on runway 16L/34R
- it is local, in the sense that each controller uses the speed vector in his own radar screen. A tool mediating the information exchange among the controllers would be much more effective.

This problem could be easily solved providing the controllers with information about the assigned runway in the label and allowing the SM LIRF to modify this information as soon as a runway change has been arranged.

**Lack of information about the sequence**

In general with full runways configuration the sequence is quite visible on the radar screen, but for cases in which a traffic landing on the east runway flies the West triangle.

Much more difficult is the visualisation of the sequence in case of single runway operations. In this case SM LIRF and SM LIRA have often been observed to check the sequence each other and with their respective TNW and TNE sector controllers in order to ensure to be all aware of it and share the same traffic picture. In addition the TN sectors controllers tended to use the speed vector to mark the aircraft in the other triangle after which their aircraft should have been turned to the merge point. This further use of the speed vector, besides those already discussed, contributes to
consider this strategy not effective.

The problem could be solved providing SM LIRF with the possibility to insert the sequence into the system and to provide TN sectors controllers with indications about this sequence. Two suggestions have been collected:

- providing the landing number in the label
- graphically show the sequence in the radar screen linking the aircraft according to the sequence order

Both solutions present possible defects in terms of usability:

- the first one implies a continuous update of the landing number as soon as the sequence proceeds, that can be fastidious and distracting for the controllers
- the second one may reveal intrusive in the radar screen and potentially distracting for the controllers

The recommendation is to use the following stage of the project to verify this need and eventually complete the collection of the requirements. A dedicated design and evaluation session will be then necessary to define the best way to provide this information.

3.6.2 Limits of display settings

Display settings have been noticed to play a key role for the effective application of PMS. The visualisation of triangles, sequencing legs and distance rings is an important means to externalise the controllers’ knowledge and support the monitoring of the traffic. Two interesting issues have been noticed during the study with respect to the way the MSP geography was represented on the radar screen. They concern:

- the display ranges available by default in the HMI
- the way the settings have to be manually changed in case of switch from PMS to conventional arrival traffic management or vice versa

In both cases the current system does not seem adequate to support the effective use of the method.
Display ranges available by default in the HMI

The system currently in use at Rome ACC provides some display default ranges that the controllers can easily set just clicking on a label.

Several cases have been observed during the study in which the use of these ranges or of a different range manually set brought the controllers to ineffective behaviours in terms of traffic management and respect of their own roles. Examples of typical effects that a wrong setting (too large, too narrow or inappropriately centred) may contribute to produce are:

- redundancy with other controllers,
- underestimations of potentially critical situations,
- ineffective use of runway capacity
- not respect of the separation at touchdown requested by the tower and consequent go around.

This problem could be solved redesigning the provision of default display ranges in the light of their possible usage.

The solution envisaged during the study is based on the idea of providing the controllers with suggestions about the correct settings to be used in each working positions, in terms not only of range but also of centre. The settings available in the radar screens of the TMA sectors are then 7, labelled respectively TNW, TNE, ARW, ARE, SM LIRF, SM LIRA and AR (to be used in single runway operations). Each of these label automatically sets the radar screen on the basis of the range and centre considered appropriated for the associated working position. The controllers remain free to change these settings manually, but in doing this activity they are conscious to be no more using the setting considered optimal for that position.

In each TMA controller working position all the settings are available. This has the twofold purpose of increasing:

- the situational awareness, since it allows the controllers to have a quick look to the situation of the colleagues
- the resilience of the system, since in case of contingency each working position can be used to display the every TMA sectors.
Manual change of the ATS geography during the transition

The modification of the ATS geography represented on the radar screens is a key activity during the transition from PMS to conventional arrival traffic management and vice versa. The experience of the fourth prototyping session highlighted that problems of situational awareness and effectiveness of the traffic management may occur in case the visualisation on the radar screen has not been updated appropriately.

A function is necessary allowing the controllers to quickly switch from PMS geography to conventional ATS geography of arrival traffic management and vice versa as soon as the transition is carried out.
Chapter 4
Conclusions and Lesson Learnt

The prototyping sessions produced positive results on the users’ acceptability and domain suitability of applying the PMS technique in the operational environment of Rome TMA.

The controllers involved in the study found the method comfortable, safe, accurate and easy to learn and to apply. In very short time they became familiar with it and able to apply it properly and effectively, even under high traffic load and in case of non nominal events. They considered the new technique suitable to and easy to accept in Rome TMA sectors, perceiving it as the evolution of the current method based on radar vectoring as result of the introduction of the PRNAV capability.

In their opinion the adoption of this method is likely to yield the following advantages:

- standardisation of the controllers performances, thus implying a standard high quality of the traffic management, less conditioned by personal skills and one’s own tolerance of traffic density and complexity
- improved teamwork, since the standardisation of the work allows to predict and anticipate the colleague’s behaviour, expectations and needs
- general reduction of controller cognitive workload in all TMA sectors, since the
standardised way of managing the arrival traffic simplifies the work and reduces the need for problem solving, continuous monitoring and R/T communication

- general high level of job satisfaction in the controllers, since the less creativity required for the arrival traffic management is counterbalanced by evident positive results in terms of spacing and runway capacity usage.

They also highlighted some drawbacks of the PMS technique, among which the following ones are worth to be reported:

- loss of flexibility with respect to the current open loop vectors technique
- conditioned applicability in certain circumstances (i.e. bad weather conditions impairing the use of both triangles and point merges), thus entailing the need for radar vectoring to continue to be applied
- concurrent application of radar vectoring and PMS method in case of traffic not 100% PRNAV equipped
- possible impact on the controllers workload in E-TMA sectors

They tended however to accept these limits as tolerable side effects of the PMS technique. They were conscious of these drawbacks, but did not consider them as limitative as to impair the acceptability of the technique itself and/or its effectiveness. On the contrary they appreciated the possibility to continue using the method even partially or in non conventional ways in the cases in which it was instead expected not to be usable at all. The management of non nominal events (i.e. bad weather, mixed equipped traffic samples and transition from PMS to radar vectoring and vice versa) confirmed these results.

Positive results have been also achieved with respect to the incremental and iterative validation approach adopted in this phase of the project. The execution of small sessions of assessment, besides allowing to test PMS in different operational scenarios of Rome TMA, confirmed to be extremely fruitful also from the validation point of view. Each session was a means to scratch hypotheses, preliminary results and possible redesign suggestions to be further checked, implemented and/or validated in the following ones. Each report was in this respect a working document intended to compare the result of the study with the ones of the previous sessions,
consolidate the results produced so far and provide recommendations and way forward for the following sessions and/or phases of the project.

In addition to the recommendation for the next stage of the project also some lessons learnt have been elicited. They are presented hereafter as a proof of the effectiveness of the approach adopted and as guidelines for future projects with a similar organisation.

**Lessons Learnt**

- Though the iterative and incremental validation approach was effective, the schedule of the prototyping sessions revealed quite narrowed to allow to full benefit by its possible benefits. The time between one session and the following one was just enough for the analysis and the provision of the report. Some more time would have been necessary to properly share the results within the project team and organise together the following session.

- The original idea of involving four different teams of controllers revealed ineffective during the study. In principle it is a means to enlarge the exposure to the PMS method and to collect a rich set of results. In reality instead the experience gathered in the second prototyping session highlighted an important side effect of this choice. The short duration of each prototyping session did not reveal adequate to allow the novices to capitalise the knowledge collected in the previous session and provide additional results. Their contribution mainly consisted in a checking and confirming the results of the previous session. A trade-off was evident between using a unique team or different teams. The first opinion was expected to produce a rich set of results, but presented the risk to introduce some biased in the results due to the limited number of controllers involved. The second opinion was expected to produce more objective results, thanks to the larger exposure, but however these results were expected to be repetitive and less detailed. In this trade off it was considered preferable to involve a unique team. This choice was considered more effective as it would have allowed to get a richer set of results concerning the use of PMS in Rome TMA. On the basis of this decision the team involved in the first session has been involved also in the third and fourth ones.

- The idea of involving some members of the project core team as controllers of
the simulation team revealed inadequate. The discrepancy of knowledge and performances was evident particularly in the second prototyping session. It produced negative results in terms of teamwork and active participation of the novices to the prototyping session. The decision to keep the team of the first session involved also in the third and fourth ones (bullet point above) allowed to overcome the problem since the controllers’ performances and knowledge tended to harmonise and be homogenous.