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SIMMOD ANALYSIS FOR BUCHAREST TMA STUDY

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TITLE:

SIMMOD ANALYSIS FOR BUCHAREST TMA STUDY

Author	**Date**	**Pages**	**Figures**	**Tables**	**Appendix**	**References**
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Abstract:

This report describes the SIMMOD capacity study performed for the Bucharest TMA

TABLE OF CONTENTS.

1. INTRODUCTION

1.1 Background

The Romanian Aviation Authorities are currently upgrading the Air Traffic Control facilities and evaluating the airspace requirements within the Romanian airspace. The evaluation will cover both Upper and Lower airspace and is being carried out with assistance from and in co-operation with the Eurocontrol Advisory Service (DEI.1) and the Eurocontrol Airspace Division (DED.4).

The project is supported by the simulation of the proposed airspace designs and operational procedures. These simulation studies will be carried out by the Eurocontrol Experimental Centre during 1996/97 and will include a real time simulation in 1997 preceded by the preparatory work in fast time.

As part of the process described above, the Romanian Civil Aviation Authority invited the Eurocontrol Airspace Division (DED.4) to assist in an evaluation of the Bucharest TMA. The goal of the TMA study is to define actions needed to provide sufficient capacity consistent with existing and forecast demand together with an optimised airspace structure.

The Airport Simulations Group (APT) at EUROCONTROL Experimental Centre were asked by DED.4 to perform a capacity study for the Bucharest TMA, using the SIMMOD[1] simulation tool. The aim of the SIMMOD simulation study is to provide data that would assist in the evaluation of the potential effects on capacity resulting from projected developments of airspace design and airport infrastructure.

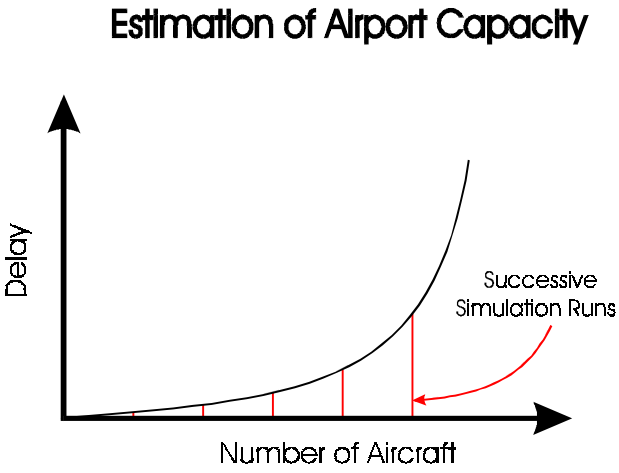
1.2 Objectives

The objective of this simulation was to perform a capacity study on the current situation at the two airports within the Bucharest TMA (Otopeni and Baneasa) and then observe the changes in capacity after three modifications had been implemented. The three modifications were:

- Deconfliction of arrival and departure routes,
- Introduction of a new taxiway parallel to Runway 26L/08R at Otopeni, and
- Introduction of simultaneous parallel runway operations at Otopeni.

[1] SIMMOD is the FAA's airspace and airport simulation model. See Annex A for details

1.3 Simulation Method - SIMMOD



The figure on the left describes the estimation of airport capacity. As the level of traffic increases so does the average aircraft delay. The delay curve rises gradually at low traffic levels but increases sharply as the airport becomes saturated with traffic. Using delay measurements, taken during the simulation, we were able to construct capacity curves for each of the simulation organisations and to then compare them.

Annex A provides an overveiw of the SIMMOD Simulation System.

1.4 Simulation Environment

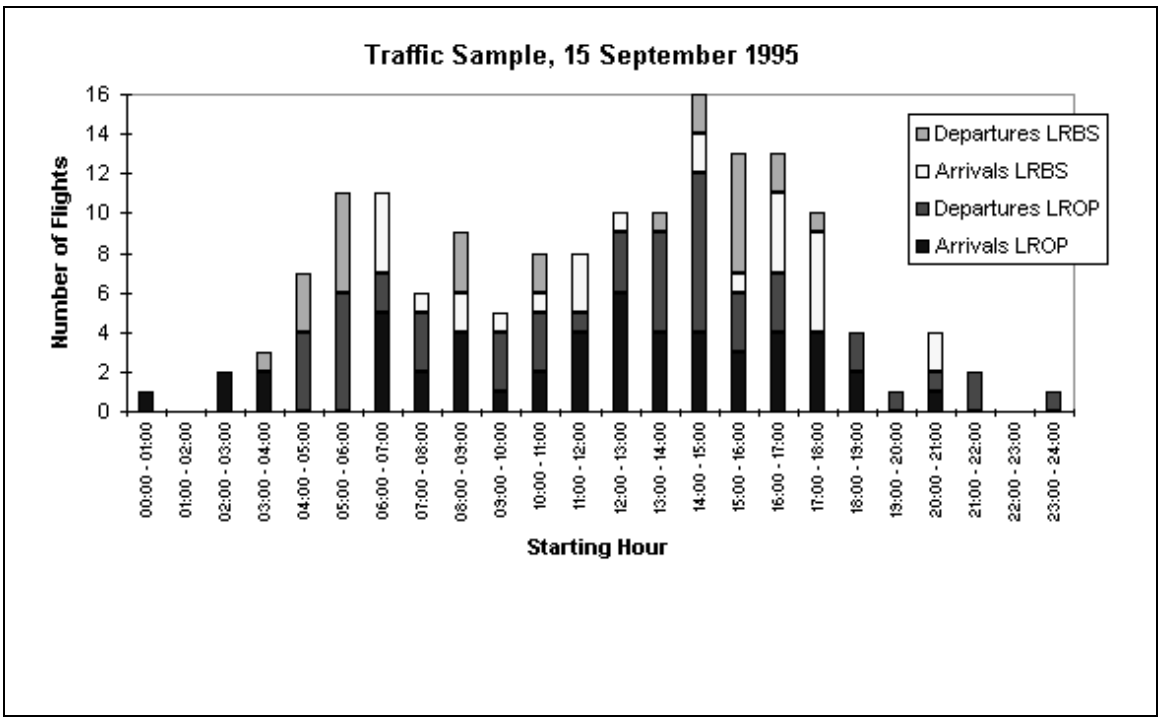
1.4.1 Simulation Data

Data were collected from The Romanian Civil Aviation Authority and The Romanian Air Traffic Services Administration and developed in conjunction with the Eurocontrol Airspace Division (DED4) for the simulation. The material included airspace and airfield data for the existing operation together with material concerning proposed modifications. For modelled scenarios with no parallel taxiway link to runway 26L threshold, the aircraft backtrack, runway occupancy time (ROT) and the resultant final approach spacings are based on the current operation.

1.4.2 Traffic Samples

The traffic sample chosen for the simulation was the actual traffic on Friday, 15 September 1995. This traffic sample was provided by the Romanian Authorities for Otopeni and Baneasa Airport. The traffic was then incrementally increased using the SIMMOD duplication feature so that the effect of an increase in future demand could be studied

The figure below illustrates the traffic sample used for Scenario One (Basecase) simulation.



1.4.3 Simulation Scenarios

1.4.3.1 General Overview

Scenario 1. Operations at Otopeni and Baneasa airports with existing traffic flows

Scenario 2. Operations at Otopeni and Baneasa with new traffic flows introduced

Scenario 3. Operations at Otopeni and Baneasa with an additional taxiway serving runway 26L/08R at Otopeni

Scenario 4. Operations at Otopeni and Baneasa with an additional taxiway serving runway 26L/08R at Otopeni with new traffic flows introduced.

Scenario 5. Parallel runway operations in segregated mode at Otopeni with Baneasa operational. New traffic flows introduced.

Scenario 6. Parallel runway operations in segregated mode at Otopeni. New traffic flows introduced . Baneasa closed.

Scenario 7. Parallel runway operations in segregated mode at Otopeni with an additional taxiway serving runway 26L/08R. New traffic flows introduced. Baneasa operational.

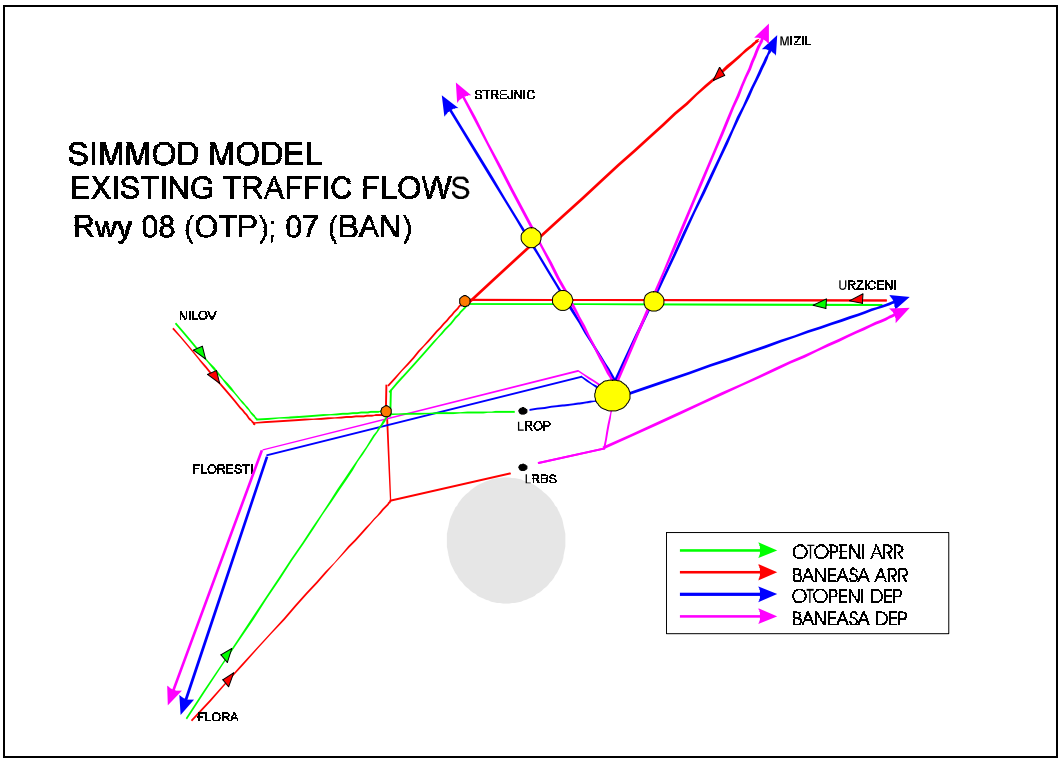
Scenario 8. Parallel runway operations in segregated mode at Otopeni with an additional taxiway serving runway 26L/08R. New traffic flows introduced. Baneasa closed.

1.4.3.2 Deconfliction of Traffic Flows

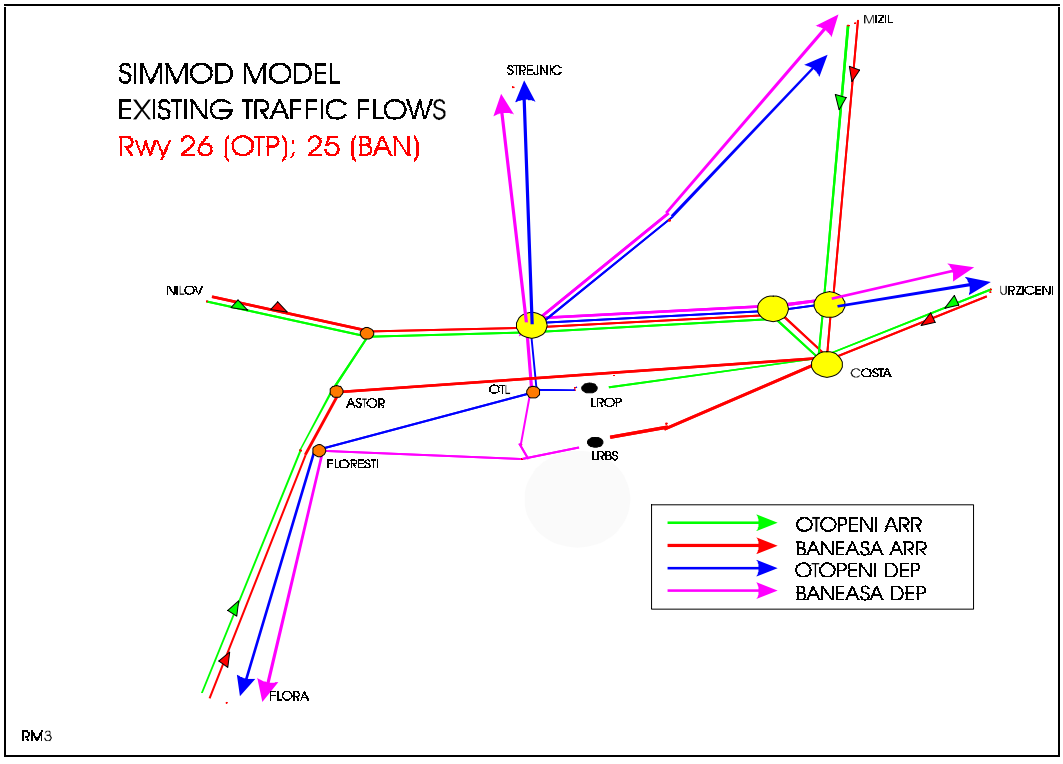
As part of the Bucharest TMA Study undertaken by the Romanian Authorities and Eurocontrol, it was proposed that arriving and departing traffic flows be altered. The purpose is to simplify co-ordination and reduce the number of potential conflicts, hence reducing Flight Deck and Controller workload during a normal flight. The existing SIDs and STARs route all traffic to the north of Otopeni, whilst the new traffic flows adopt routings to the south of Otopeni. Noise abatement procedures for these new routings have not, as yet, been developed. This simulation study, however, does take account of possible future noise procedures by simulating organisations with aircraft avoiding the city (see Chapter 2. RESULTS) and with aircraft overflying the city (see Annex B). The TMA study stops short of a complete SID and STAR re-design as factors such as terrain clearance, noise and environmental issues are outside of its scope.

Diagrams illustrating the existing and proposed traffic flows used by SIMMOD in this simulation study can be found on the following pages.

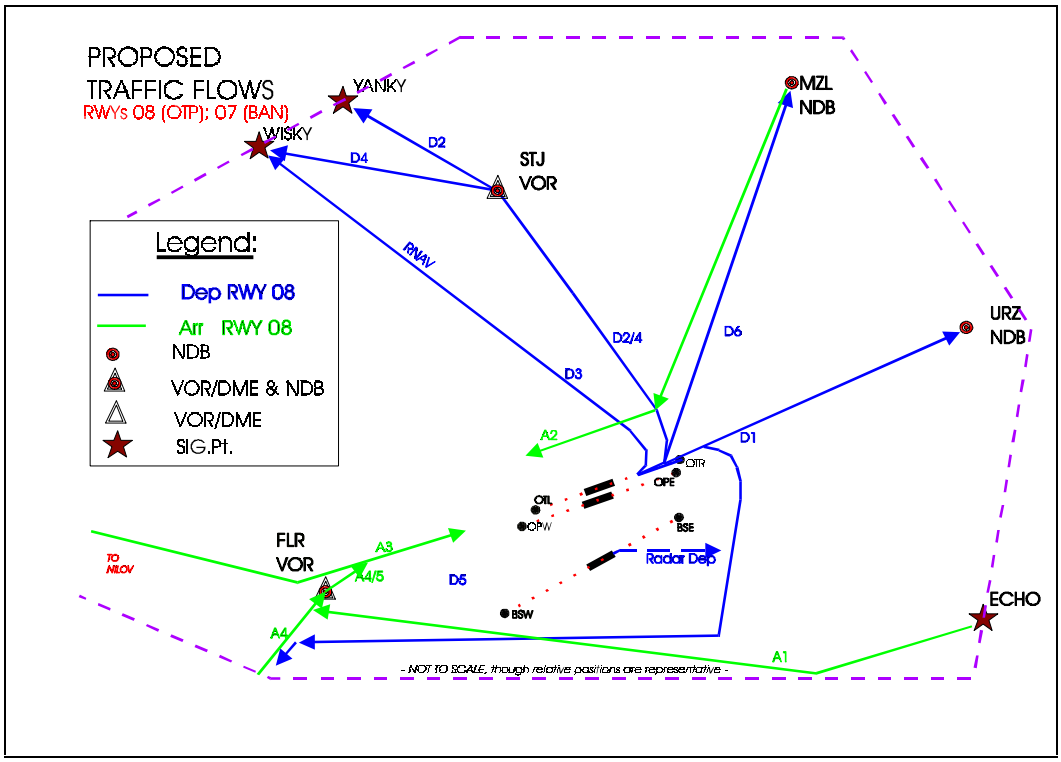
1.4.3.2.1 EXISTING TRAFFIC FLOWS: RUNWAY LROP 08 / LRBS 07



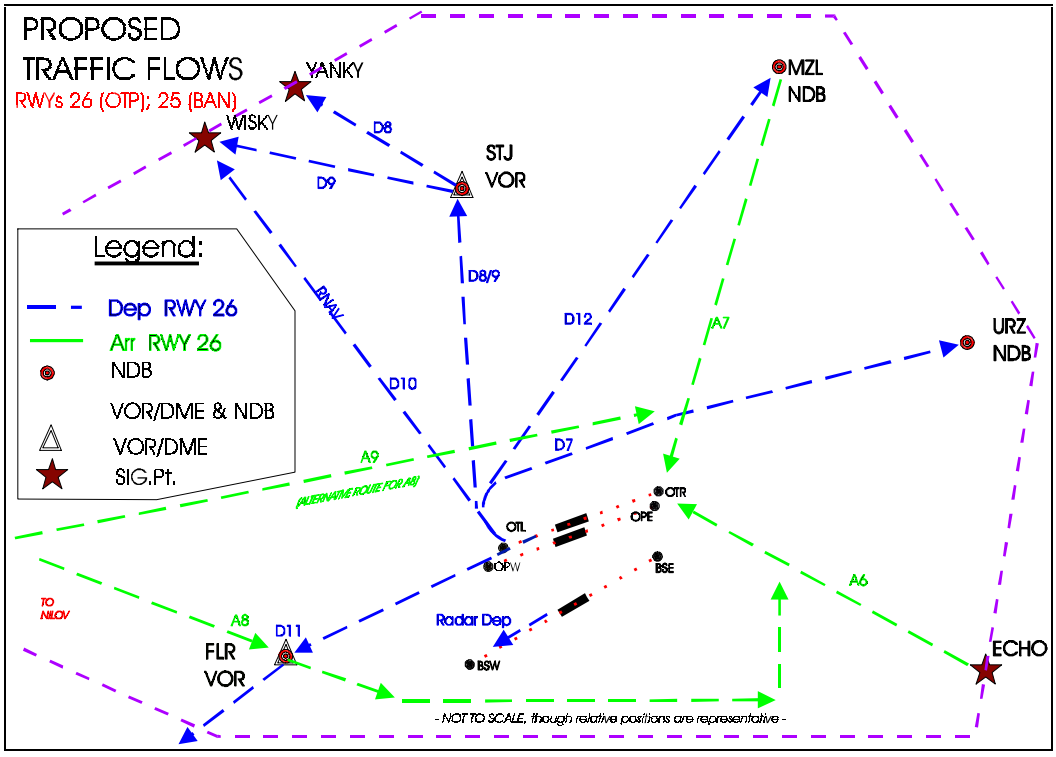
1.4.3.2.2 EXISTING TRAFFIC FLOWS: RUNWAY LROP 26 / LRBS 25



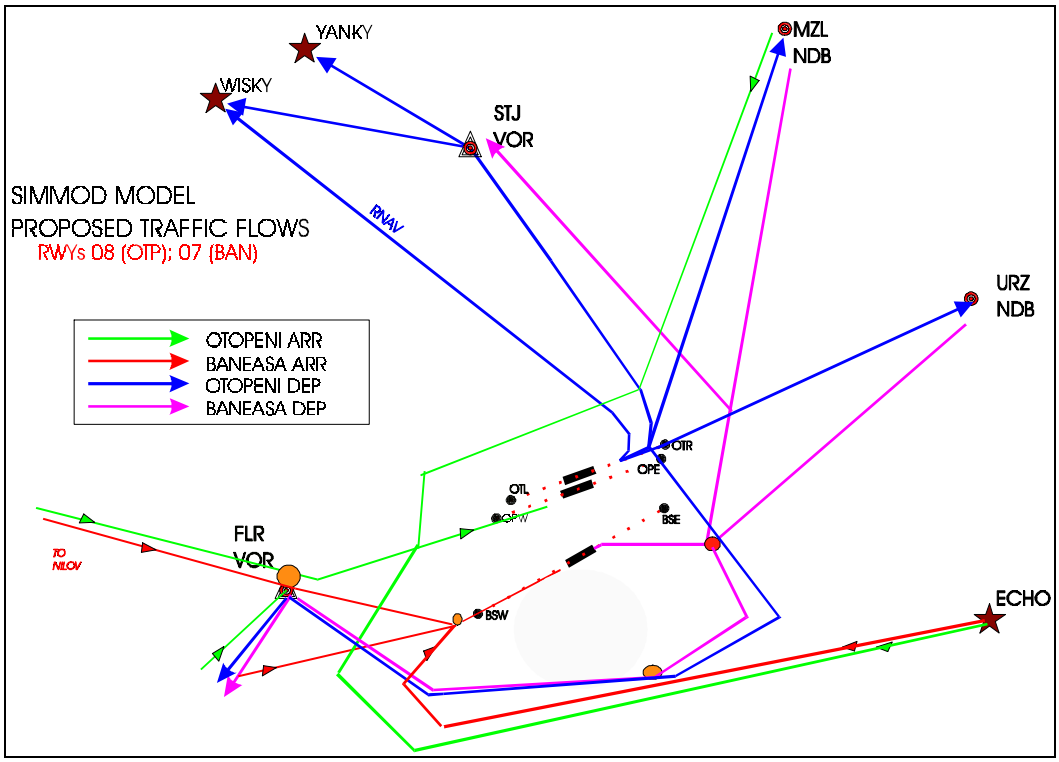
1.4.3.2.3 PROPOSED NEW TRAFFIC FLOWS: AVOIDING THE CITY - RUNWAY LROP 08 / LRBS 07



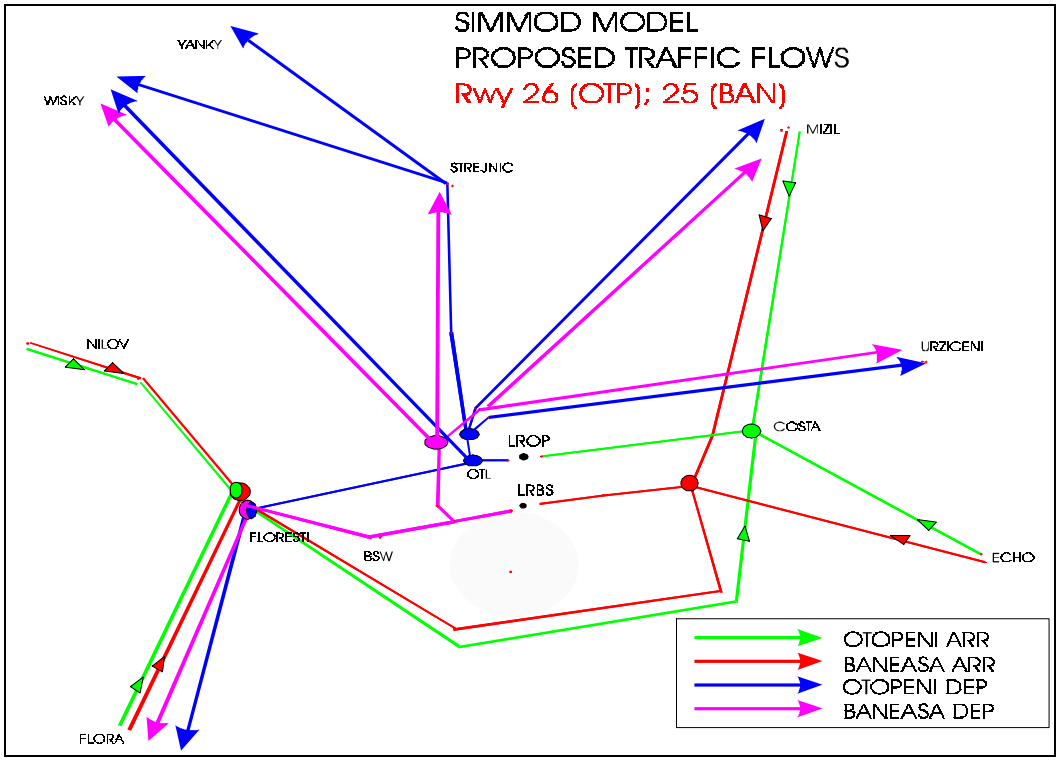
1.4.3.2.4 PROPOSED NEW TRAFFIC FLOWS: AVOIDING THE CITY - RUNWAY LROP 26 / LRBS 25



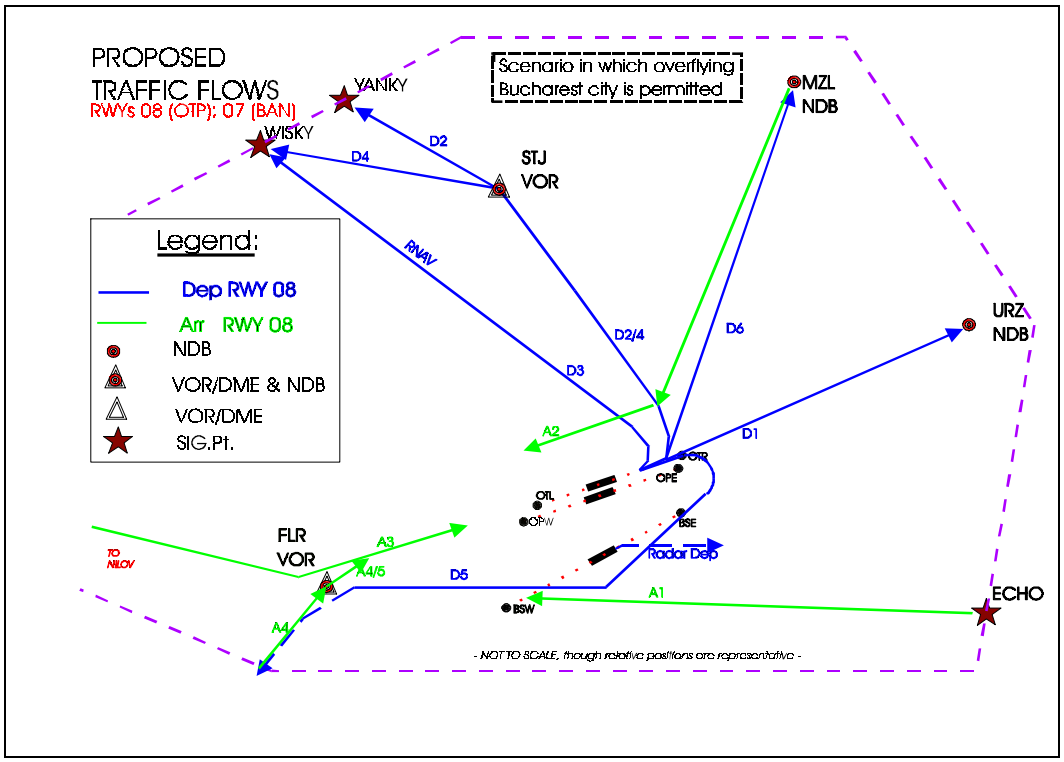
1.4.3.2.5 SIMULATED NEW TRAFFIC FLOWS: AVOIDING THE CITY - RUNWAY LROP 08 / LRBS 07



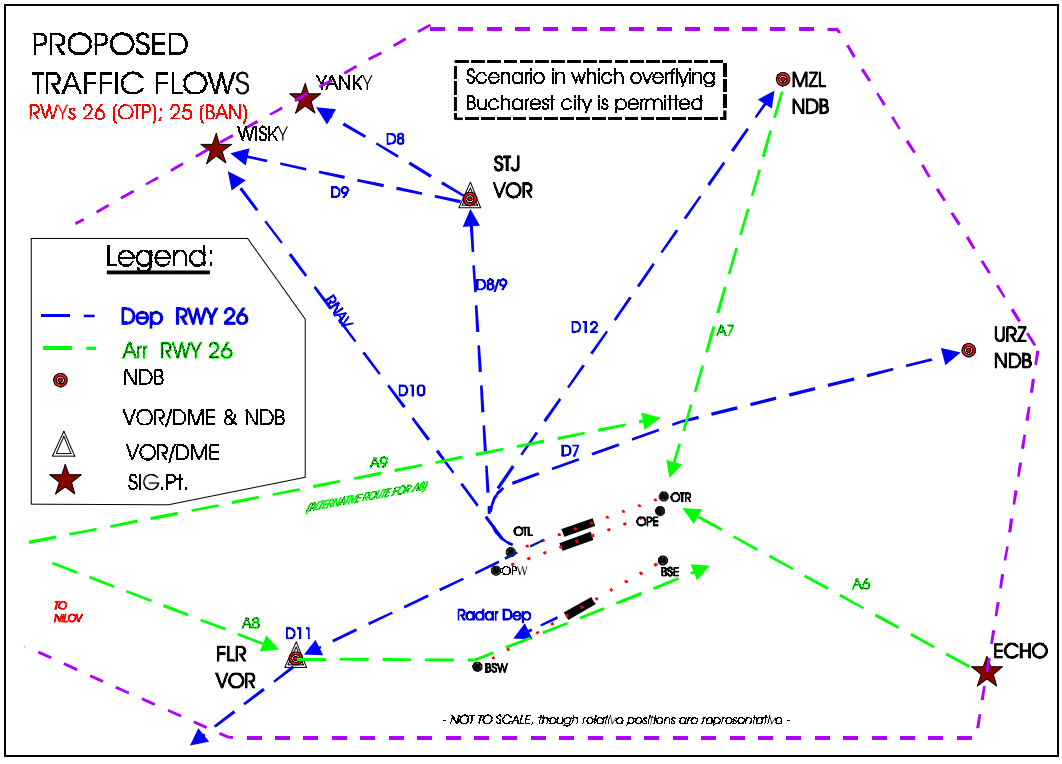
1.4.3.2.6 SIMULATED NEW TRAFFIC FLOWS: AVOIDING THE CITY - RUNWAY LROP 26 / LRBS 25



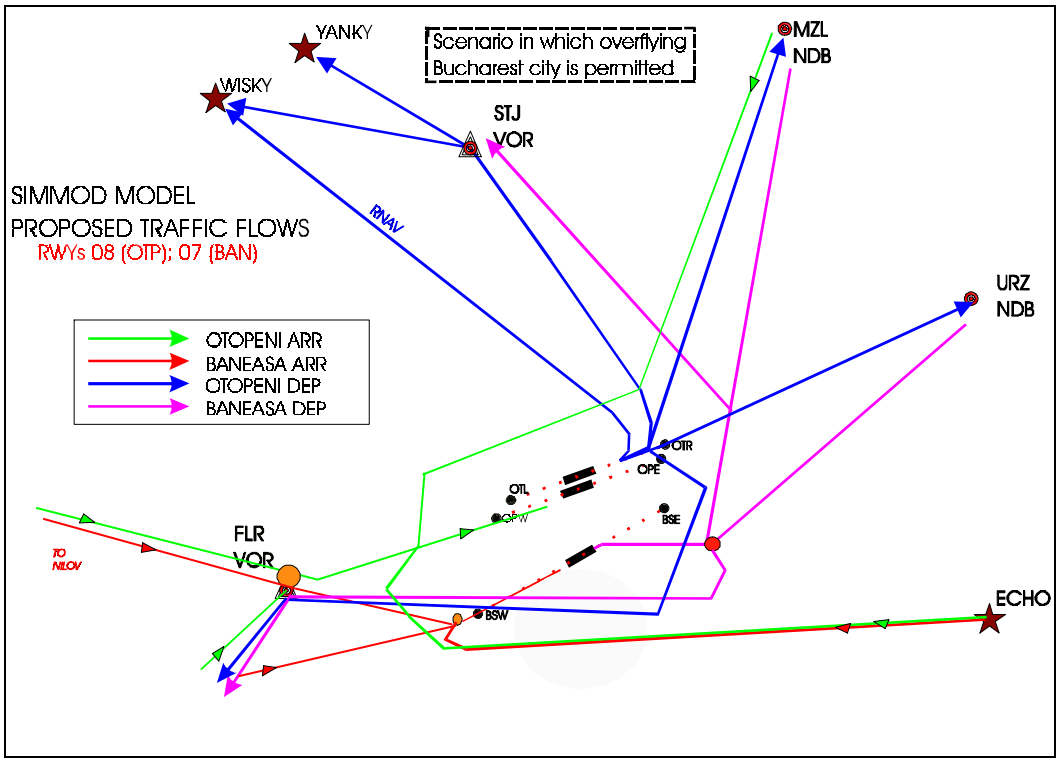
1.4.3.2.7 PROPOSED NEW TRAFFIC FLOWS: OVER THE CITY - RUNWAY LROP 08 / LRBS 07



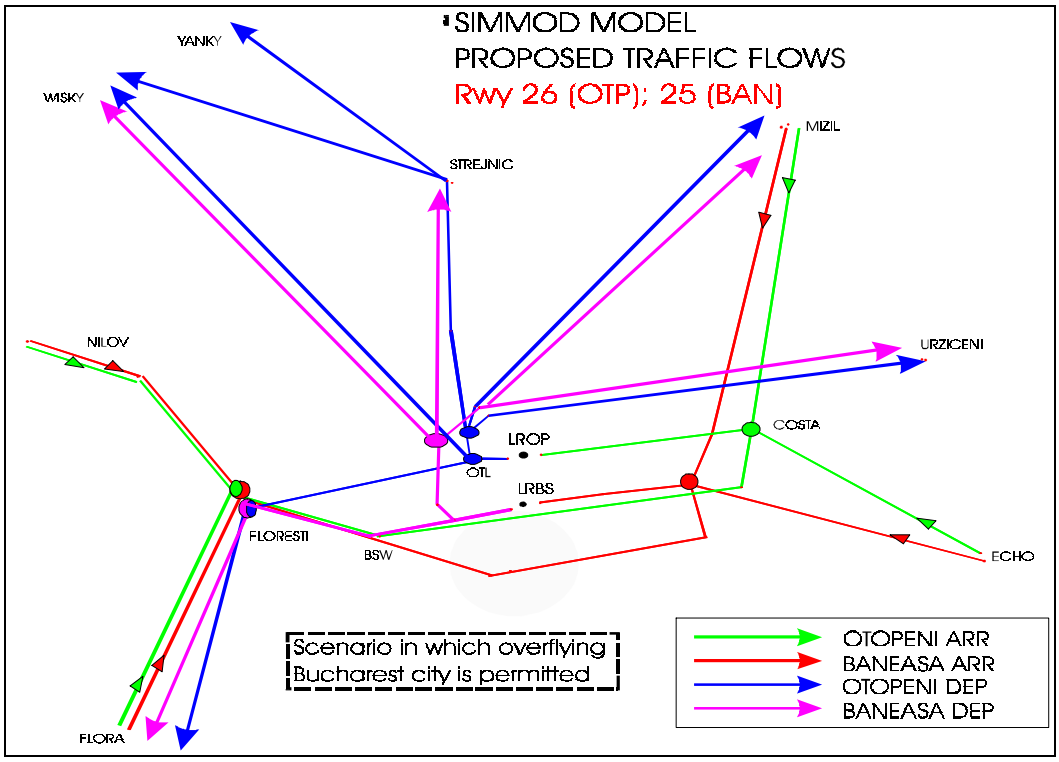
1.4.3.2.8 PROPOSED NEW TRAFFIC FLOWS: OVER THE CITY - RUNWAY LROP 26 / LRBS 25



1.4.3.2.9 SIMULATED NEW TRAFFIC FLOWS: OVER THE CITY - RUNWAY LROP 08 / LRBS 07



1.4.3.2.10 SIMULATED NEW TRAFFIC FLOWS: OVER THE CITY - RUNWAY LROP 26 / LRBS 25



1.4.3.3 Additional Taxiway Parallel to Runway 26L/08R, Otopeni

Phase One of the Otopeni International Airport Master Plan[2] proposes single runway operation with the construction of a parallel taxiway connecting Taxiway D and the runway 26L threshold.

The new taxiway was simulated in conjunction with the other proposed changes as detailed in this section, 1.4.3 Simulation Scenarios. Scenarios where the additional taxiway was implemented examined the potential capacity benefits resulting from the reduced runway occupancy time. Added to this is the positive impact on the overall airport safety case, with taxiway access at both ends of the runway removing the need for backtracking. Further potential reductions in runway occupancy are also expected in Phase 3 of the Development Plan with the proposed introduction of rapid runway exit taxiways; however, this proposal was not included in this simulation study.

1.4.3.4 Introduction of Simultaneous Parallel Runway Operations at Otopeni

Otopeni Airport consists of two staggered parallel runways (orientation 26/08) 1260 metres apart with a stagger of 685 metres. 08R has the westerly threshold. This configuration allows for simultaneous operations on the two runways, in segregated mode, given that certain criteria are met[3].

Phase 2 (starting year 2002/2003) of the Otopeni International Airport Master Plan proposes resurfacing and re-equipping runway 26R/08L to allow segregated parallel operations. When runway 08 is in operation, 08R will be used for landing traffic and 08L for departing traffic. When runway 26 is in operation, 26R will be used for landing traffic and 26L for departing traffic.

An alternative strategy under consideration is to re-surface and re-equip runway 26R/08L thus implementing simultaneous operations first, with the taxiway development following in later phases. Whilst this would increase the airport's capacity, it would not eliminate the need for arrivals and departures to backtrack.

Simultaneous parallel runway operations are simulated in this study both with and without the additional taxiway described above (1.4.3.3 Additional Taxiway Parallel to Runway 26L/08R, Otopeni).

[2] Otopeni International Airport Master Plan has been developed by Romairport (a combined Romanian and Italian company). This development plan is structured in three phases: a short term phase (until year 2000), a medium term phase (until year 2010) and a long term phase (for after 2010). Those parts of the Masterplan, relevant to this study, are described in Chapter 5 of the Eurocontrol Document, Evaluation of Terminal Airspace in Romania (July 1996)

[3] These criteria are detailed in ICAO Annex 14. PANS-RAC Doc 4444, PANS-OPS Doc 8168 and the Manual of Simultaneous Operations on Parallel or Near-Parallel Runways (Doc 9642)

1.4.3.5 Baneasa Airport

Baneasa airport consists of a single runway (orientation 07/25), which is served by a limited taxiway structure connecting the apron with the western end and the mid point of the runway. Existing operations require that certain arrivals and departures backtrack before landing or after take-off.

The proportion of future traffic which will be required to backtrack will depend on the traffic mix. Thus development proposals for Baneasa are dependant upon the number and type of future operations. Currently, Baneasa is operated as a separate entity from Otopeni Airport with regard to airport development. As yet, there is no Master Plan for the development of Baneasa Airport.

In this simulation study, Baneasa Airport is modelled with today's runway and taxiway configuration using the traffic mix as described in section 1.4.2 Traffic Samples page 15. In Scenarios Six and Eight it is assumed that Baneasa Airport is closed.

1.4.3.6 The Simulation Organisations

The two tables below give a brief summary of the simulation organisations for each of the eight scenarios used in the simulation study.

1.4.3.6.1 Summary for Scenarios One, Two , Three and Four.

	TRAFFIC LEVEL ⇓	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**	**SCENARIO 4**
Runway 26 LROP 25 LRBS	155 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
	233 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
	311 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
	350 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
Runway 08 LROP 07 LRBS	155 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
	233 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
	311 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows
	350 Flights	• Basecase	• New Traffic Flows	• Taxiway Addition to Runway 26L/08R LROP	• Taxiway Addition • New Traffic Flows

1.4.3.6.2 Summary for Scenarios Five, Six, Seven and Eight.

	TRAFFIC LEVEL ⇓	**SCENARIO 5**	**SCENARIO 6**	**SCENARIO 7**	**SCENARIO 8**
Runway 26 LROP 25 LRBS	155 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
	233 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
	311 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
	350 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
Runway 08 LROP 07 LRBS	155 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
	233 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
	311 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed
	350 Flights	• New Traffic Flows • LROP Segregated Mode	• New Traffic Flows • LROP Segregated Mode • Baneasa Closed	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode	• Taxiway Addition • New Traffic Flows • LROP Segregated Mode • Baneasa Closed

1.5 Measurements

As this study focuses on the increase in airport capacity (as reflected in annual aircraft delays), the measure of Average Total Delay per aircraft was used for the analysis. A number of other measurements were also calculated, by SIMMOD, pertaining to aircraft delay and travel time.

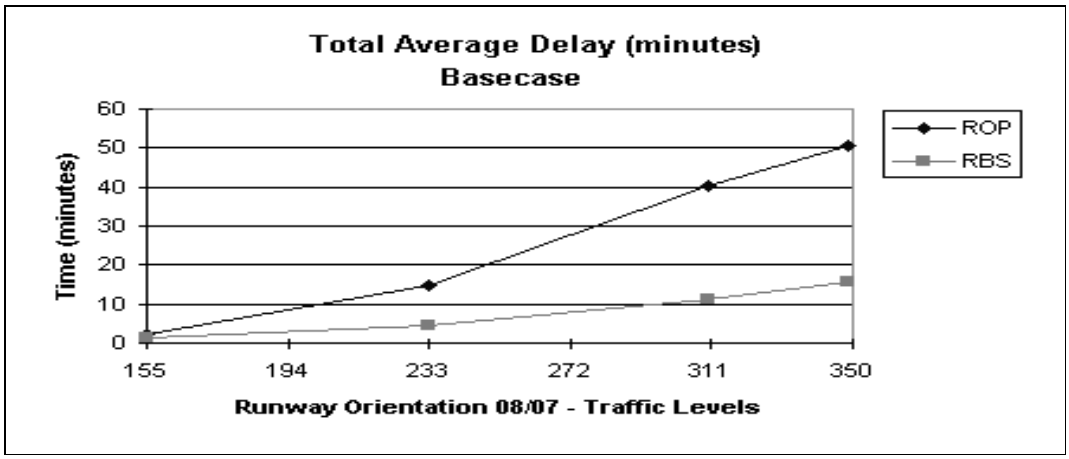
Average Total Delay Graphs for Avoiding the City can be found in Chapter Two Results. The relevant tables can found in Annex B on pages B1 and B2; tables and graphs illustrating Average Travel Time can also be found in Annex B. The results section also includes a simple delay cost savings analysis.

Annex B also includes graphs and tables for Over the City, as well as, graphs and tables for the peak hour (14h00 to 15h00) for Avoiding the City.

2. RESULTS

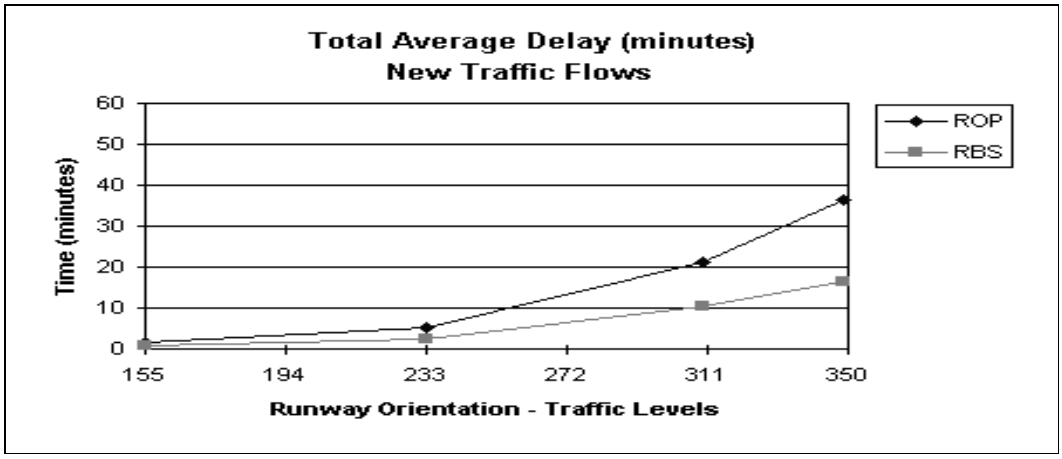
2.1 AVOIDING THE CITY - RUNWAY 08/07

2.1.1 SCENARIO ONE: BASECASE



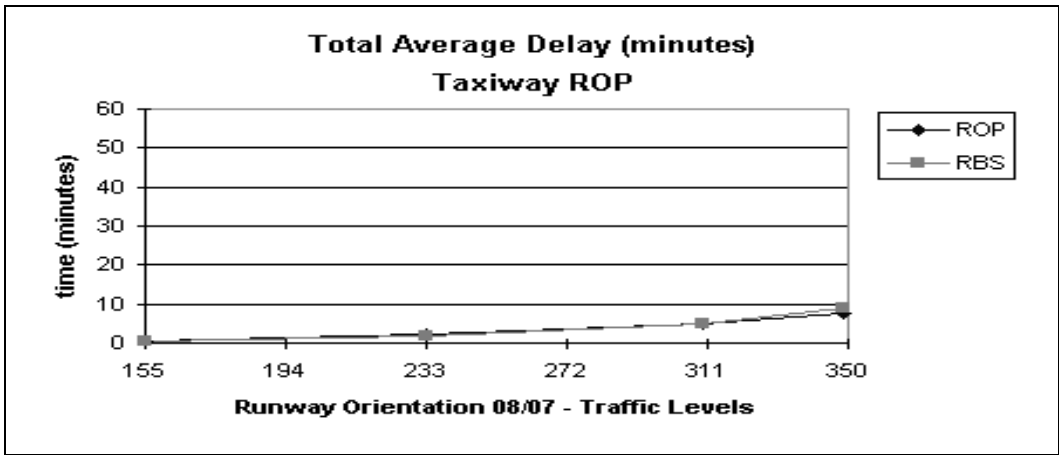
The figure above illustrates the Total Average Delay for the current situation in the Bucharest TMA. Both Otopeni and Baneasa, at traffic level 155 flights, have an acceptable delay of less than ten minutes. Increasing the traffic results in increasing delay for both Otopeni and Baneasa. Otopeni's delay increases more markedly than Baneasa, which is to be expected as Baneasa handles fewer operations than Otopeni.

2.1.2 SCENARIO TWO: NEW TRAFFIC FLOWS



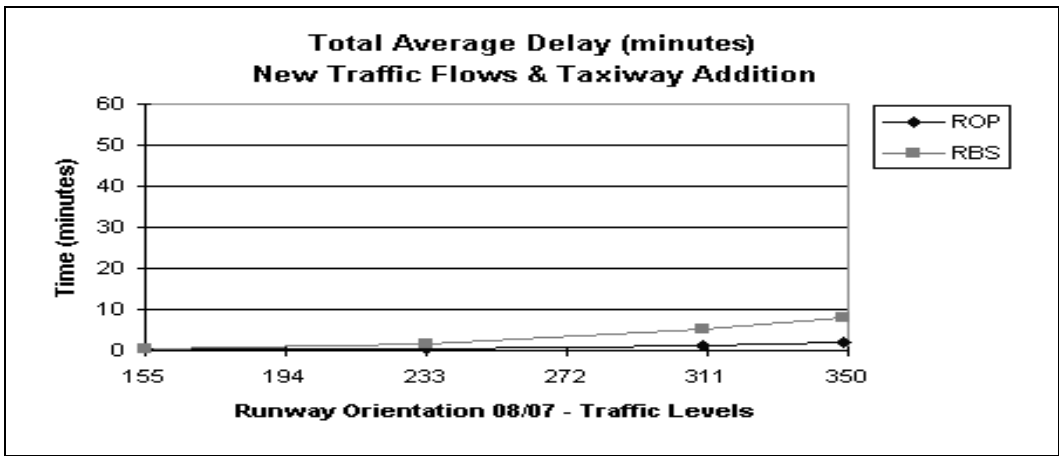
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows. A decrease in the overall delay results are seen; however, for both Otopeni and Baneasa the delay figures for traffic levels 311 flights and 350 flights are still above ten minutes.

2.1.3 SCENARIO THREE: NEW TAXIWAY ADDITION AT LROP



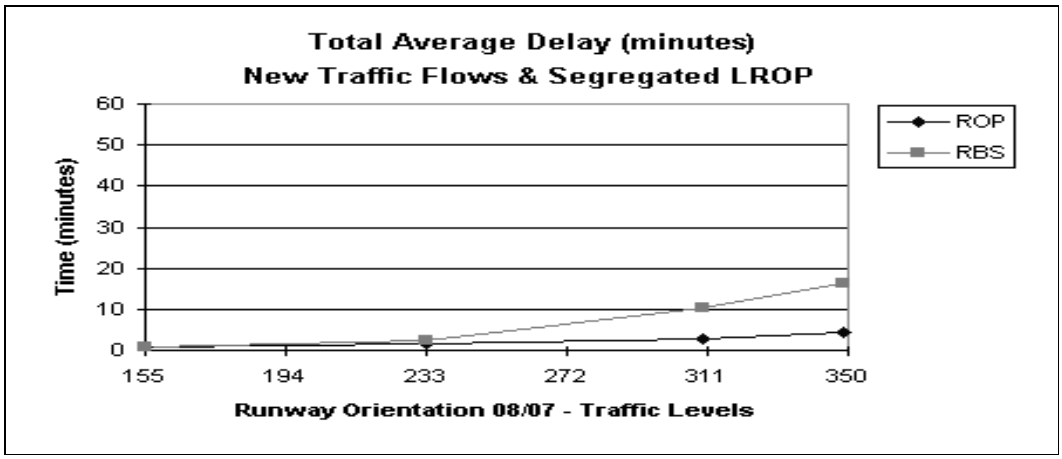
The figure above illustrates the Total Average Delay after the implementation the new taxiway addition parallel to runway 26L/08R at Otopeni. The implementation of the new taxiway is clearly beneficial. Delay at Otopeni is below ten minutes for all traffic levels. Baneasa also enjoys a decrease in delay. Otopeni and Baneasa have virtually no difference in expected delay.

2.1.4 SCENARIO FOUR: NEW TRAFFIC FLOWS & TAXIWAY ADDITION



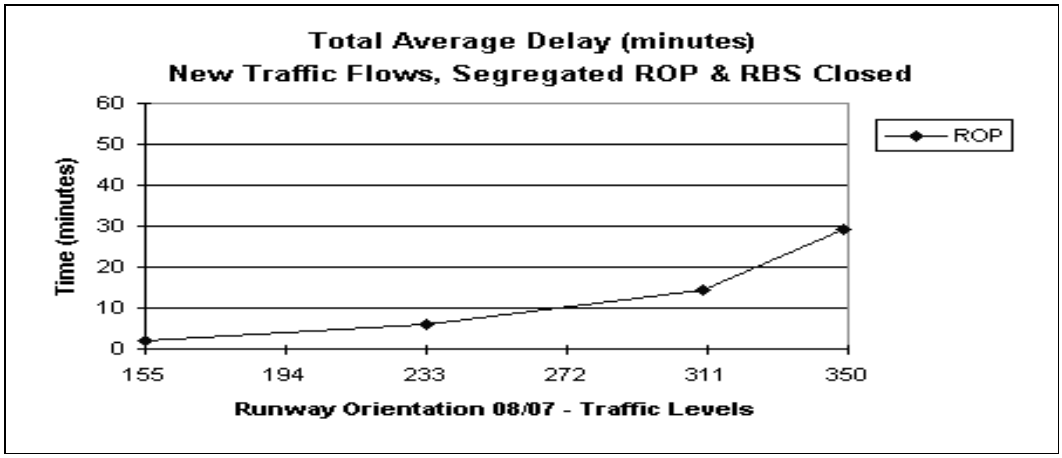
The table above illustrates the Total Average Delay after the implementation of both the new traffic flows and the new taxiway addition. The benefits of these two implementations is clearly seen at Otopeni: expected delay has been reduced to less than two minutes for all traffic levels. Baneasa experiences a fractional decrease when compared to the results of Scenario Three. However, when compared to Scenario Two, the expected delay for Baneasa has been significantly reduced, indicating that the proposed structural change at Otopeni has a positive effect on operations at Baneasa.

2.1.5 SCENARIO FIVE: NEW TRAFFIC FLOWS & LROP SEGREGATED



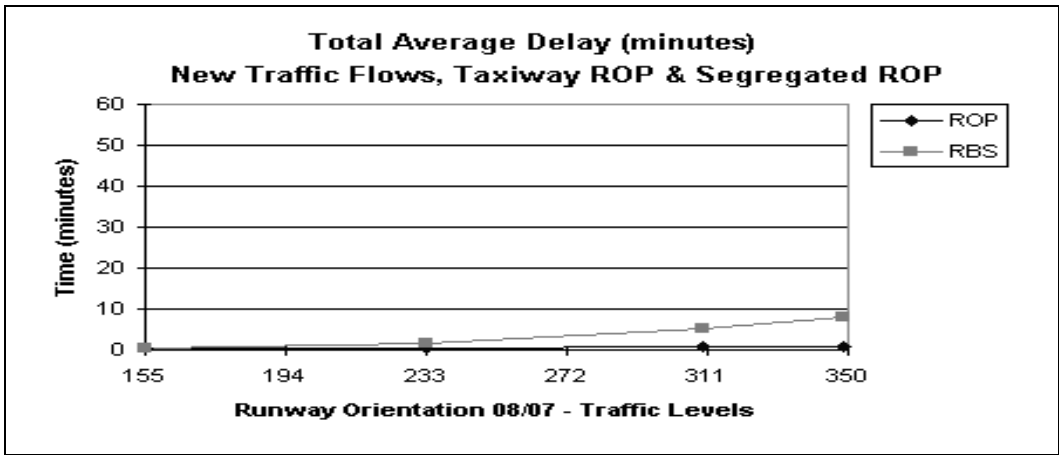
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows, along with segregated parallel operations at Otopeni. When compared to the Basecase, the expected delay has been significantly reduced for both Otopeni and Baneasa. The delay values for Otopeni are less than those found in Scenario Two and Scenario Three, but greater than those for Scenario Four. This indicates that the implementation of segregated operations at Otopeni, in conjunction with the new traffic flows, has had a significant effect on the expected delay (less than five minutes for all traffic levels) but not as significant as the implementation of the new taxiway in conjunction with the new traffic flows (less than two minutes for all traffic levels).

2.1.6 SCENARIO SIX: NEW TRAFFIC FLOWS, LROP SEGREGATED & LRBS CLOSED



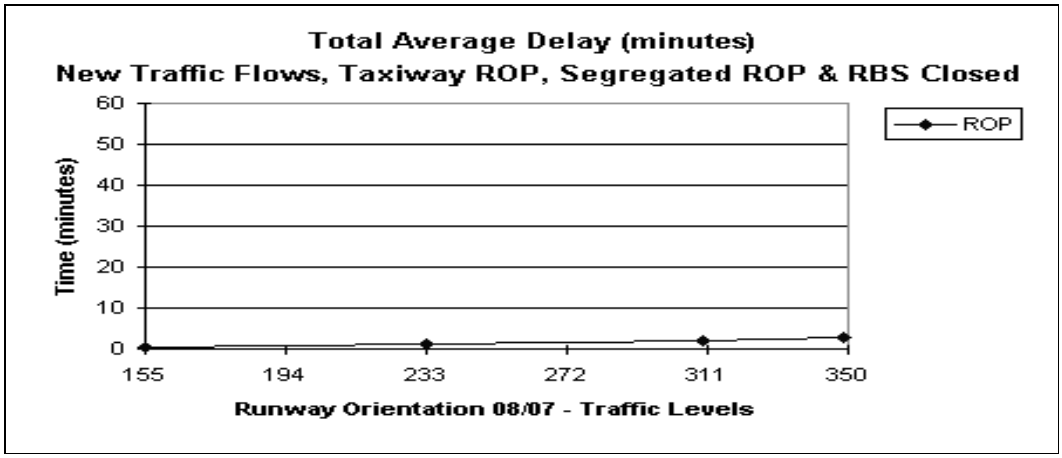
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows, segregated parallel operations at Otopeni and the closure of Baneasa Airport. Whilst the expected delay for Otopeni is considerably reduced when compared to the Basecase, when Scenario Six is compared to Scenarios Two, Three, Four and Five the expected delay is higher for all traffic levels. This would indicate that, if the new taxiway addition is not implemented, the implementation of the new traffic flows, as well as segregated operations at Otopeni, is most beneficial with Baneasa in operation.

2.1.7 SCENARIO SEVEN: NEW TRAFFIC FLOWS, TAXIWAY ADDITION, LROP SEGREGATED



The figure above illustrates the Total Average Delay after the implementation of the new traffic flows with the new additional taxiway and segregated parallel operations at Otopeni. The expected delay for Otopeni has been significantly reduced, being below one minute for all traffic levels - the most beneficial so far. Baneasa shows the same results as for Scenario Four. This indicates that the implementation of the new taxiway at Otopeni benefits the operations at both Otopeni and Baneasa whereas the implementation of segregated operations only benefits Otopeni.

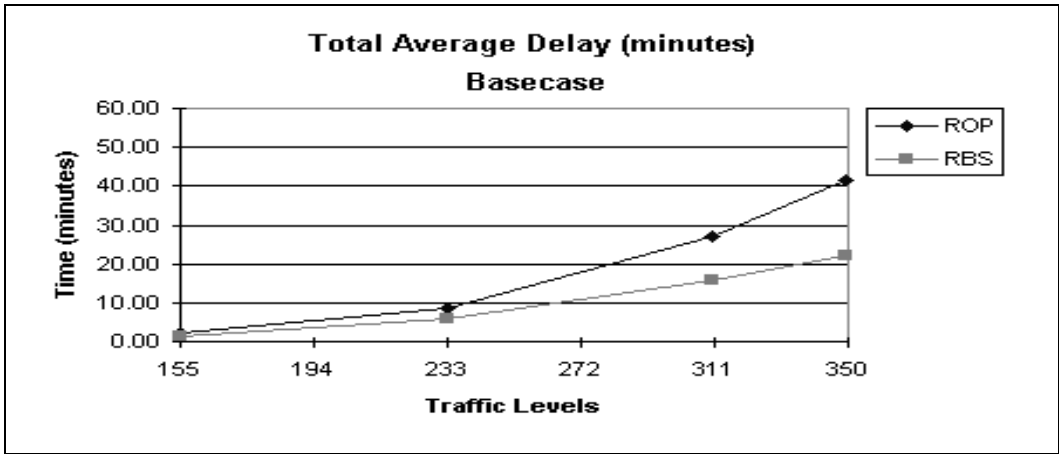
2.1.8 SCENARIO EIGHT: NEW TRAFFIC FLOWS, TAXIWAY ADDITION, LROP SEGREGATED & LRBS CLOSED



The figure above illustrates the Total Average Delay after the implementation of the new traffic flows, the new taxiway addition, segregated operations at Otopeni and the closure of Baneasa Airport. Whilst the expected delay for Otopeni might be higher in scenario eight than in Scenario Seven, the overall expected delay for the Bucharest TMA traffic is less than three minutes - by far the most beneficial of all the scenarios.

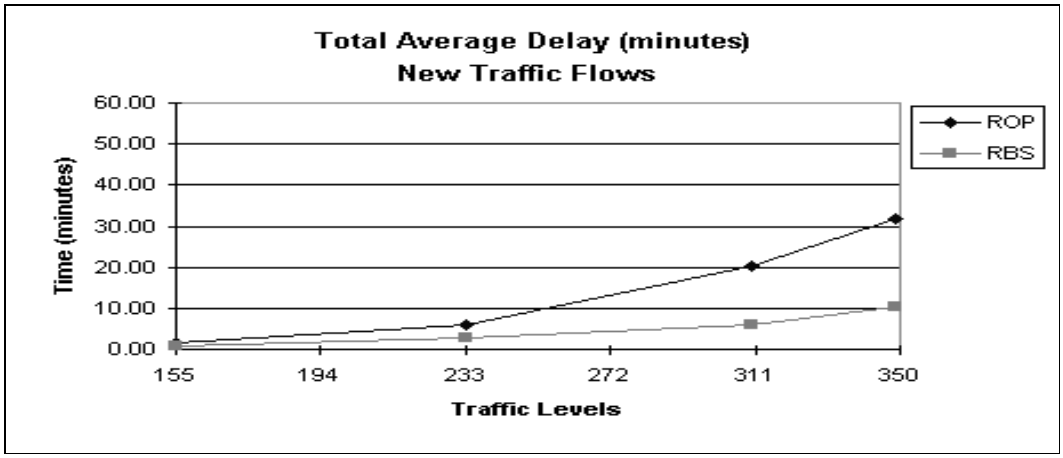
2.2 AVOIDING THE CITY - RUNWAY LROP 26/ LRBS 25

2.2.1 SCENARIO ONE: BASECASE



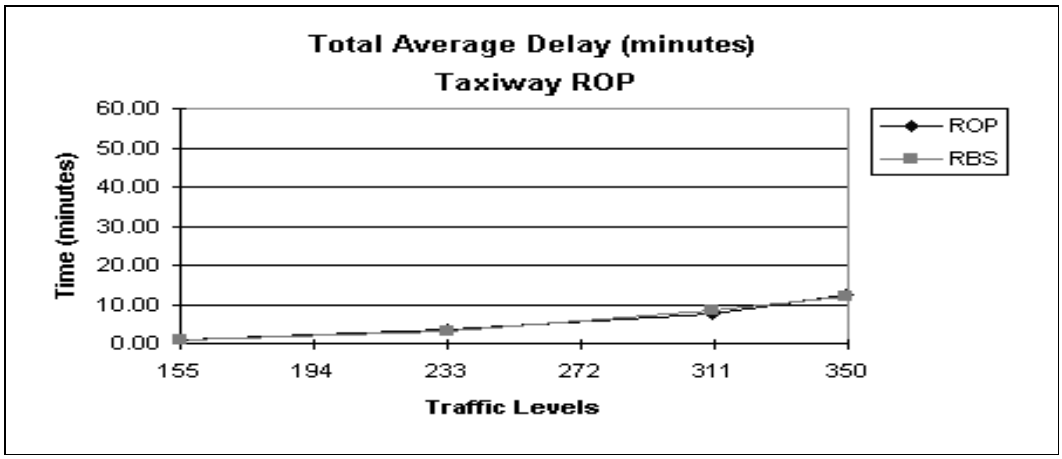
The figure above illustrates the Total Average Delay for the current situation in the Bucharest TMA. Both Otopeni and Baneasa, at traffic level 155 flights, have an acceptable delay of less than ten minutes. Increasing the traffic results in increasing delay for both Otopeni and Baneasa. Otopeni's delay increases more markedly than Baneasa, which is to be expected as Baneasa handles fewer operations than Otopeni. When compared to the Runway 08/07 Basecase, Otopeni has lower expected delay values and Baneasa has slightly higher.

2.2.2 SCENARIO TWO: NEW TRAFFIC FLOWS



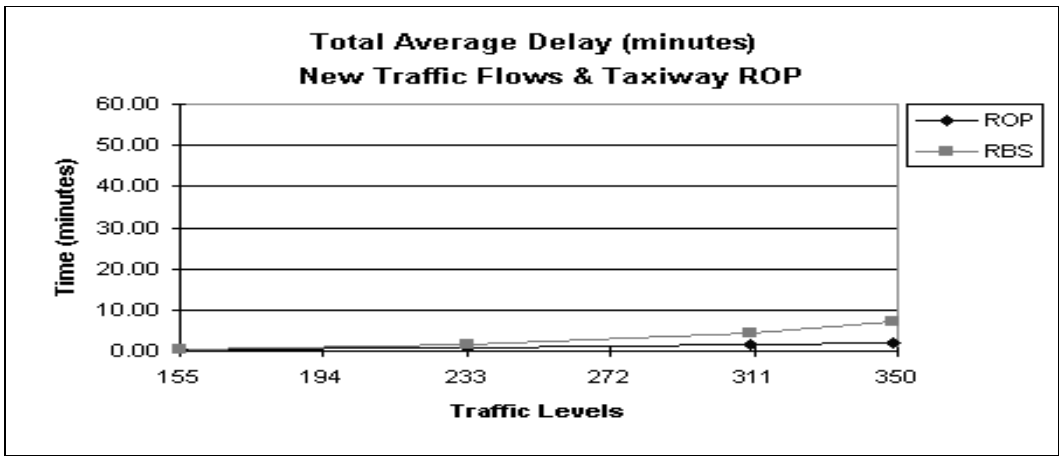
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows. A decrease in the overall delay results are seen; however, for both Otopeni (traffic levels 311 flights and 350 flights) and Baneasa (traffic level 350 flights) the delay figures are still above ten minutes. The new traffic flows appear to have a more beneficial effect when runway 26/25 is in operation when one compares this scenario Two with Scenario Two for Runway 08/07 (see page 16).

2.2.3 SCENARIO THREE: NEW TAXIWAY ADDITION AT LROP



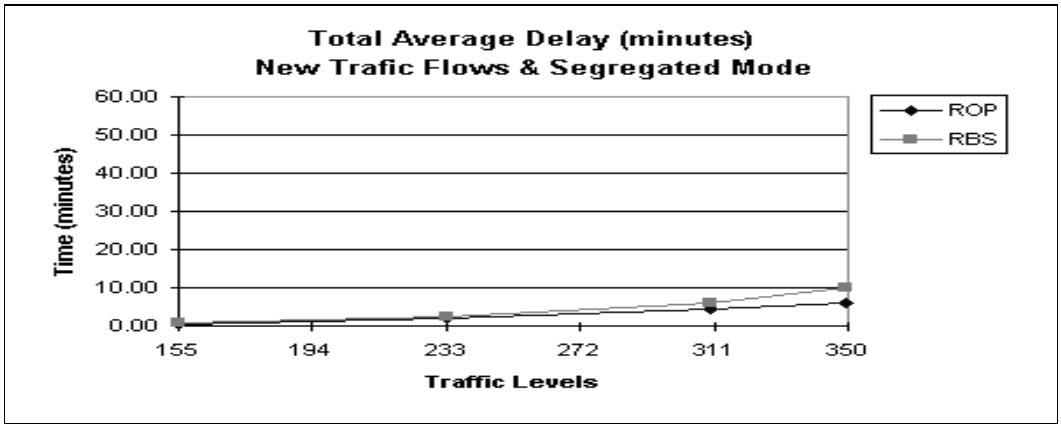
The figure above illustrates the Total Average Delay after the implementation of the new taxiway addition parallel to runway 26L/08R at Otopeni. The implementation of the new taxiway is clearly beneficial. Delay at Otopeni is below thirteen minutes for all traffic levels. Baneasa also enjoys a decrease in delay when compared to the Basecase but there is a slight increase when compared to Scenario Two. Otopeni and Baneasa have virtually no difference in expected delay.

2.2.4 SCENARIO FOUR: NEW TRAFFIC FLOWS & NEW TAXIWAY ADDITION



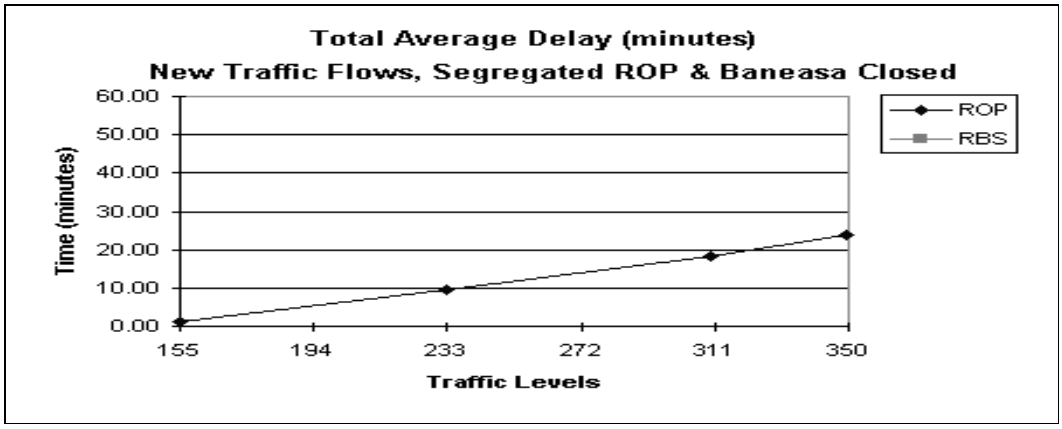
The table above illustrates the Total Average Delay after the implementation of both the new traffic flows and the new taxiway addition. The benefits of these two implementations is clearly seen at Otopeni: expected delay has been reduced to less than two minutes for all traffic levels. Baneasa experiences a fractional decrease when compared to the results of Scenario Three. However, when compared to Scenario Two, the expected delay for Baneasa has been significantly reduced, indicating that the proposed structural change at Otopeni also reduces delays for operations at Baneasa. When compared to Runway 08/07 Scenario Four (see page 17) the delay values are very similar.

2.2.5 SCENARIO FIVE: NEW TRAFFIC FLOWS & LROP SEGREGATED



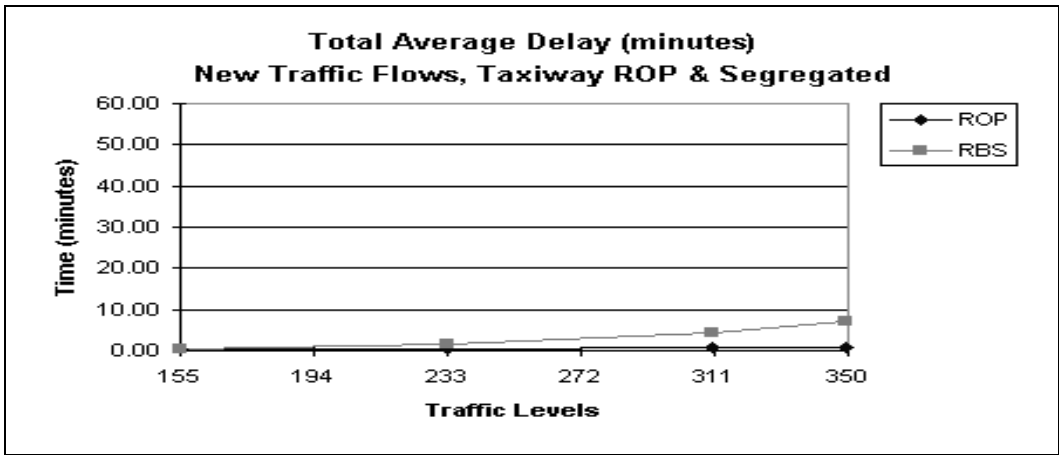
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows, along with segregated operations at Otopeni. When compared to the Basecase, the expected delay has been significantly reduced for both Otopeni and Baneasa. The delay values for Otopeni are less than those found in Scenario Two and Scenario Three, but greater than those for Scenario Four. This indicates that the implementation of segregated operations at Otopeni, in conjunction with the new traffic flows, has had a significant effect on the expected delay (less than seven minutes for all traffic levels) but not as significant as the implementation of the new taxiway in conjunction with the new traffic flows (less than two minutes for all traffic levels). When compared to Runway 08/07 Scenario Five (see page 17), Runway 26/25 Scenario Five has slightly higher delay values

2.2.6 SCENARIO SIX: NEW TRAFFIC FLOWS, LROP SEGREGATED & LRBS CLOSED



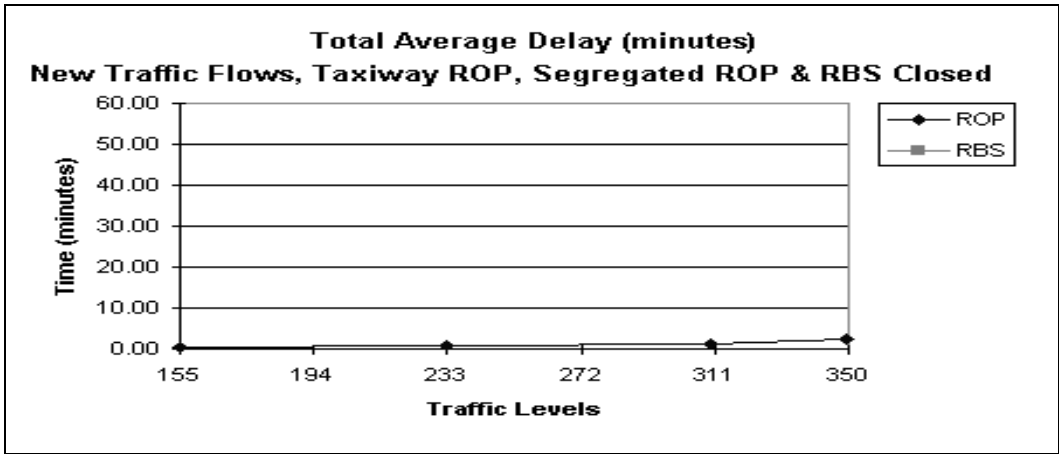
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows, segregated operations at Otopeni and the closure of Baneasa Airport. Whilst the expected delay for Otopeni is considerably reduced when compared to the Basecase, when Scenari0 Six is compared to Scenarios Two, Three, Four and Five the expected delay is higher for all traffic levels. This would indicate that, if the new taxiway addition is not implemented, the implementation of the new traffic flows, as well as segregated operations at Otopeni, is most beneficial with Baneasa in operation. When compared to Runway 08/07 Scenario Six (see page 18), Runway 26/25 Scenario Six delay values are slightly lower.

2.2.7 SCENARIO SEVEN: NEW TRAFFIC FLOWS, NEW TAXIWAY ADDITION & LROP SEGREGATED



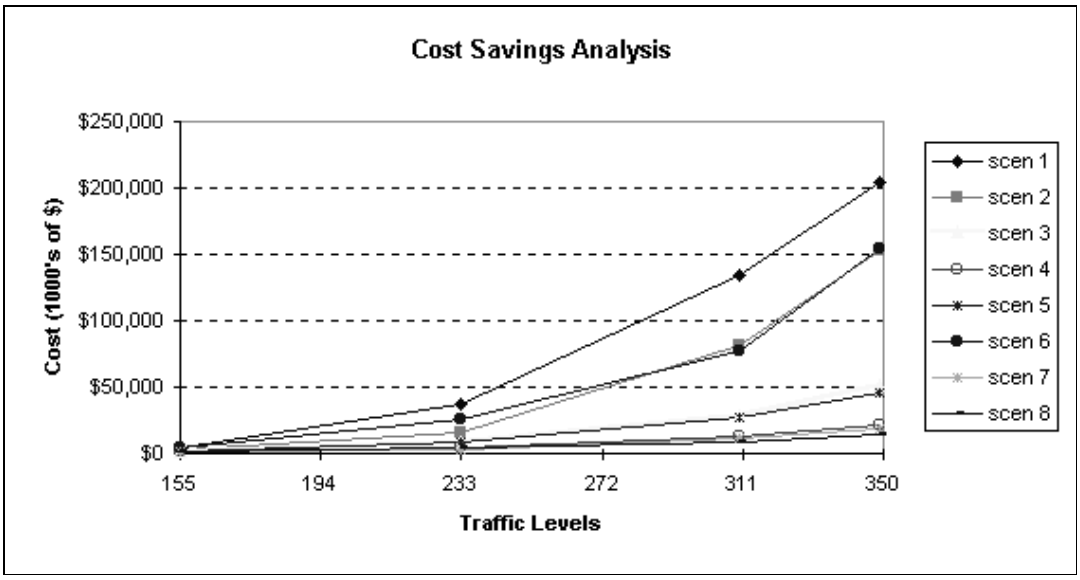
The figure above illustrates the Total Average Delay after the implementation of the new traffic flows with the new additional taxiway and segregated operations at Otopeni. The expected delay for Otopeni has been significantly reduced, being below one minute for traffic levels - the most beneficial so far. Baneasa shows that same results as for Scenario Four. This indicates that the implementation of the new taxiway at Otopeni benefits the operations at both Otopeni and Baneasa whereas the implementation of segregated operations only benefits Otopeni. When compared to Runway 08/07 Scenario Seven (see page 19), the results are very similar

2.2.8 SCENARIO EIGHT: NEW TRAFFIC FLOWS, NEW TAXIWAY ADDITION, LROP SEGREGATED & LRBS CLOSED



The figure above illustrates the Total Average Delay after the implementation of the new traffic flows, the new taxiway addition, segregated operations at Otopeni and the closure of Baneasa Airport. Whilst the expected delay for Otopeni might be higher in scenario eight than in Scenario Seven. The overall expected delay for the Bucharest TMA is less than two minutes - by far the most beneficial of all the scenarios. When compared to Runway 08/07 Scenario Eight (see page 19), the results are very similar.

2.3 COST SAVINGS ANALYSIS



The annualised cost figures were computed by first averaging the daily delay per aircraft in minutes by arrivals, departures and runway. These figures were then annualised and weighted by annual percentage use for each runway orientation (70 % for Runway 08/07 and 30% for Runway 26/25) to provide the annualised delay in minutes. Then, using an average aircraft operating cost of $3000[4] per hour, these figures were transformed to represent annualised delay cost. The figure above illustrates these costs. Clearly the most beneficial scenarios are Scenario 4 (New Traffic Flows and Taxiway Addition), Scenario 7 (New Traffic Flows, New Taxiway Addition and Segregated Operations at Otopeni) and Scenario Eight (New Traffic Flows, New Taxiway Addition, Segregated Operations and Baneasa Closed).

The relevant costing tables can be found below.

The table below illustrates the annualised delay time for the Bucharest TMA.

ANNUALISED DELAY (MINUTES)									
Ops/ day	Ops/ year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
155	49000	98000	68000	35000	19000	33000	86000	16000	21000
233	74000	736000	328000	173000	74000	154000	523000	65000	71000
310	98000	2708000	1614000	569000	268000	533000	1532000	225000	171000
349	110000	4106000	3041000	1028000	443000	913000	3045000	376000	273000

[4] The estimate of $3000 per hour for the average operating cost was determined from historical cost data collected by AEA. Actual operating costs may vary. Alternative costs may be applied if needed.

The table below illustrates the annualised costs at $3000 per hour for the Bucharest TMA.

ANNUALISED COST @ $3000 PER HOUR ($USA in 1 000 000's)									
Ops/ day	Ops/ year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
155	49000	$5	$3	$2	$1	$2	$4	$1	$1
233	74000	$37	$16	$9	$4	$8	$26	$3	$4
310	98000	$135	$81	$29	$13	$27	$77	$11	$9
349	110000	$205	$153	$52	$22	$46	$154	$19	$14

The table below illustrates what the expected differences in operating cost savings would be between the present situation (Scenario One: Basecase) and the other eight scenarios.

VARIANCE OF INCREMENTAL COST TO BASECASE ($USA in 1000 000's)									
Ops /day	Ops/ year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
155	49000	0	-$2	-$3	-$4	-$3	-$1	-$4	-$4
233	74000	0	-$21	-$28	-$33	-$29	-$11	-$34	-$33
310	98000	0	-$54	-$106	-$122	-$108	-$58	-$124	-$126
349	110000	0	-$52	-$153	-$183	-$159	-$51	-$186	-$191

3. CONCLUSIONS

- Runway Orientation: the similarity between the delay results for both runway orientations indicate that runway orientation does not have a significant effect on the expected delay for Bucharest TMA.

- New Traffic Flows reduced the expected delay for both Otopeni and Baneasa.

- Taxiway Addition at Otopeni significantly reduced delay at Otopeni, as well as at Baneasa.

- Segregated Operations at Otopeni, when implemented in conjunction with the new traffic flows, had a significant effect on the expected delay for Otopeni but none for Baneasa. When implemented in conjunction with the new traffic flows and the new taxiway addition both airports benefited from significant reductions in delay.

- Baneasa: With the implementation of both the parallel taxiway and segregated parallel operations at Otopeni, sufficient capacity appears to be provided to accommodate both Baneasa and Otopeni traffic, for all traffic levels, at the one airport.

4. RECOMMENDATIONS

The results of this study indicate that the phased development proposed in the Otopeni Masterplan and developed in the TMA study matches expected capacity with forecast traffic during the next eight years.

Phase one of the Master Plan development proposes single runway operations with taxiway access to runway ends. The results of this study indicate that this approach is sound. In this configuration, increased capacity is achieved by reduced runway occupancy through removal of the backtrack requirement.

Introduction of parallel runway operations may be considered as a first development phase if other factors dictate this. However, whilst providing Otopeni with increased runway capacity, the need to backtrack is not removed and runway occupancy times remain high. At traffic levels beyond forecast 1998 levels Baneasa operations are affected by this.

Baneasa operations are simulated in this study based on current operations with applied forecasting. If the intended level and type of operations are changed, it is recommended that a further capacity study be carried out.

Traffic forecasts will be continuously refined with the benefit of experience and to reflect development of operational plans for Otopeni and Baneasa. As these become available it is recommended that a further capacity study be made to measure the capacity of single runway operations with optimised taxiway structure beyond the forecasts 2004 traffic level addressed by this study. Similarly, although introduction of simultaneous parallel runway operations at Otopeni together with an optimised taxiway structure clearly provides adequate capacity at forecast 2004 traffic mix and level, measurement of capacity beyond that may be required.

Furthermore, Bucharest TMA operations are simulated in this study based on current traffic mix and level with a growth factor applied to that base traffic. Should the operational fleet mix change, or growth exceed simulated levels, a new capacity study may be necessary.

Bucharest TMA, as with the majority of airports associated with terminal airspace, is subject to a “peak and trough” traffic pattern. Nevertheless, scheduling at both Otopeni and Baneasa should be examined as existing peaks significantly influence capacity requirements when forecasts are applied.

It is recommended that Standard Instrument Departure and Arrival procedures be developed using the Eurocontrol TMA evaluation document as a basis. Operational procedures relating to the interaction between Otopeni and Baneasa could be developed at that time

5. ANNEX A

How are the end results achieved ?

The complete air and ground system is represented by a network of points and connecting segments along which the aircraft 'navigate'. Along with other point qualities, an altitude is associated to each point. This altitude is usually derived from free profiles but can be modified to represent, for example, height restrictions, SIDs, STARs, etc.

The simulation module is the core of the SIMMOD system. The module traces the "steps" through time and space of each aircraft defined in the traffic sample from one point to the next along its route. Potential violations of any of the modelled separation requirements between two or more aircraft moving towards a given point are detected and then resolved by adjusting their arrival times at the point. Depending on the importance of this adjustment, the controller action deemed to be causing it is interpreted as either track adjustment, speed control, holding or re-routeing of aircraft. Such specific occurrences as overtaking in the air, shuffling aircraft in the departure queue, as well as many other ATC procedures and actions either on the aerodrome, in the approach/departure environment or in en-route airspace can be simulated by careful selection of the input parameters.

Input requirements
The SIMMOD input is constructed in a number of files. The validity and correctness of the input data is crucial for the accuracy and realism of the simulation. The SIMMOD files constructed will contain detailed information regarding:

- Geographical boundaries of airspace and restrictions,
- Geographical boundaries of sectors and restrictions (capacities),
- Points data and restrictions (separation standards),
- Route data and restrictions (separation standards),
- Airfield data and restrictions (aircraft size limitations),
- Aircraft data and restrictions (wake turbulence),
- Scheduling of events (list of flights), and
- Weather considerations (reduced visibility operations).

Output
Output data is produced in a report format which may also be converted into charts and graphs. The data available from SIMMOD includes:

Airfields, which includes:

- Runway utilisation,
- Ground delays at gates, holding points or during taxiing,
- Average times for completing ground movements.

Sectors, which includes:

- Total number of aircraft that crossed the sectors within a specified time period,
- Maximum number of aircraft in each sector's area of responsibility at any one time within a specified time period,
- Average flight times for the sectors,
- A workload index for the sectors, and
- Number of aircraft in level flight, climbing or descending for each sector within a specified time period.

Points, which includes:

- Rate of traffic flow over points,
- Number of aircraft climbing, descending or in level flight at a point,
- Number of potential conflicts that will require ATC intervention.

Routes, which includes:

- Average flight times on each route, and
- Number of aircraft on each route.

Simulation Animation

In addition to the output data, the SIMMOD post-processor module produces an animated high resolution colour display of the simulation. All aircraft can be displayed during all stages of flight, or ground movement, following procedures defined in the input data.

During the animation run various items can be analysed:

- Evolution of a traffic situation and traffic flow,
- A visual check of the simulation's realism,
- Verification that procedures defined for the model do not violate the defined separation specifications, and
- Areas of scheduling congestion can be located.

Disadvantages - Limitations

SIMMOD is designed as a "quick look" simulation tool and has the following limitations:

- No resolution of conflicts during a simulation by changing an aircraft's level, and

- A global view only, no detail regarding an individual controller or operating position

6. ANNEX B: DATA MEASUREMENTS

6.1 AVOIDING THE CITY

6.1.1 RUNWAY 08 LROP / 07 LRBS - AVERAGE TOTAL DELAY (MINUTES)

			Average Total Delay (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	2.38	1.16
		233	14.67	4.37
		310	40.20	11.22
		349	50.78	15.65
Scenario 2	New Traffic Flows	155	1.74	0.68
		233	5.35	2.51
		310	21.01	10.40
		349	36.40	16.34
Scenario 3	Taxiway	155	0.65	0.55
	Addition LROP	233	2.04	1.79
		310	4.85	5.13
		349	7.57	9.01
Scenario 4	New Traffic Flows &	155	0.30	0.47
	Taxiway Addition	233	0.52	1.69
		310	1.34	5.29
		349	1.89	8.09
Scenario 5	New Traffic Flows &	155	0.70	0.68
	LROP Segregated	233	1.66	2.51
		310	2.85	10.39
		349	4.22	16.36
Scenario 6	New Traffic Flows,	155	2.04	
	LROP Segregated &	233	6.01	
	LRBS Closed	310	14.49	
		349	29.32	
Scenario 7	New Traffic Flows,	155	0.24	0.47
	Taxiway Addition &	233	0.39	1.69
	LROP Segregated	310	0.72	5.29
		349	0.99	8.09
Scenario 8	New Traffic Flows,	155	0.43	
	Taxiway Addition,	233	1.04	
	LROP Segregated &	310	1.81	
	LRBS Closed	349	2.70	

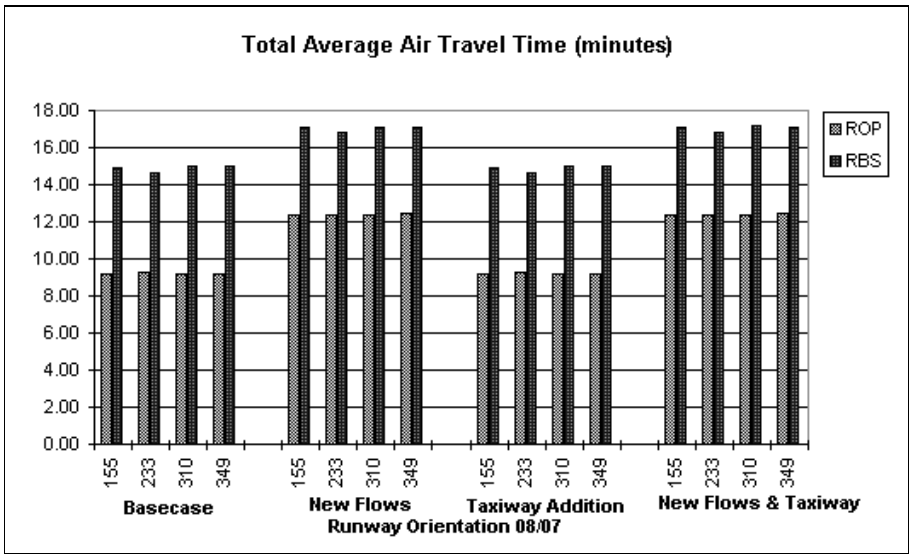
6.1.2 RUNWAY 26 LROP / 25 LRBS - AVERAGE TOTAL DELAY (MINUTES)

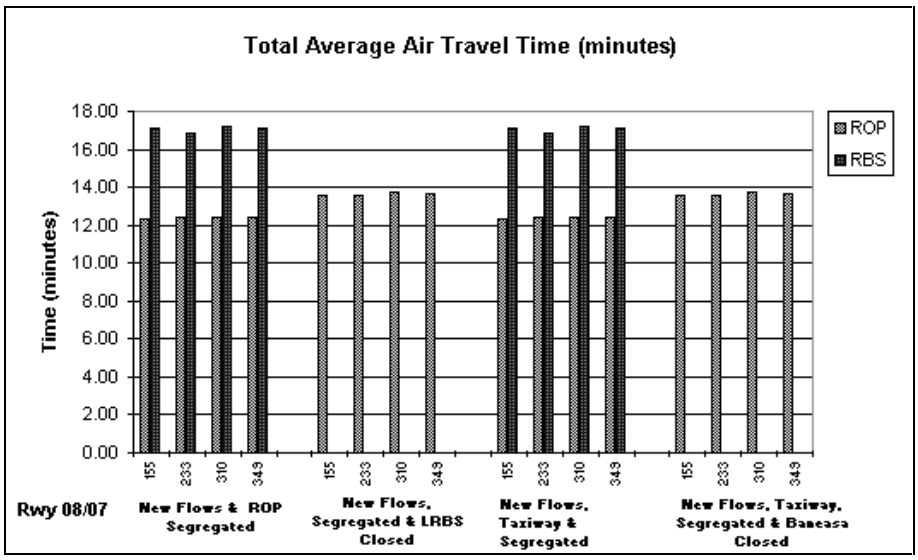
			Average Total Delay (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	2.37	1.44
		233	8.76	6.01
		310	27.07	15.81
		349	41.58	21.91
Scenario 2	New Traffic Flows	155	1.77	0.69
		233	6.01	2.59
		310	20.30	6.14
		349	31.96	10.19
Scenario 3	Taxiway Addition LROP	155	0.93	1.04
		233	3.46	2.90
		310	7.47	8.31
		349	12.37	12.15
Scenario 4	New Traffic Flows & Taxiway Addition	155	0.40	0.52
		233	0.73	1.72
		310	1.56	4.31
		349	1.91	7.10
Scenario 5	New Traffic Flows & LROP Segregated	155	0.60	0.69
		233	2.16	2.59
		310	4.29	6.13
		349	6.14	10.19
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	155	1.10	
		233	9.56	
		310	18.29	
		349	23.86	
Scenario 7	New Traffic Flows, Taxiway Addition & LROP Segregated	155	0.26	0.54
		233	0.42	1.72
		310	0.69	4.25
		349	0.86	7.10
Scenario 8	New Traffic Flows, Taxiway Addition, LROP Segregated & LRBS Closed	155	0.49	
		233	0.95	
		310	1.29	
		349	2.33	

6.1.3 RUNWAY 08 LROP / 07 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - TABLE

			Average Air Delay (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	9.20	14.92
		233	9.30	14.67
		310	9.17	15.01
		349	9.17	14.98
Scenario 2	New Traffic Flows	155	12.37	17.09
		233	12.40	16.82
		310	12.34	17.06
		349	12.41	17.10
Scenario 3	Taxiway Addition LROP	155	9.20	14.92
		233	9.30	14.67
		310	9.17	15.01
		349	9.17	14.98
Scenario 4	New Traffic Flows & Taxiway Addition	155	12.37	17.09
		233	12.40	16.82
		310	12.40	17.19
		349	12.41	17.10
Scenario 5	New Traffic Flows & LROP Segregated	155	12.37	17.09
		233	12.40	16.82
		310	12.40	17.19
		349	12.41	17.10
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	155	13.58	
		233	13.58	
		310	13.70	
		349	13.66	
Scenario 7	New Traffic Flows, Taxiway Addition & LROP Segregated	155	12.37	17.09
		233	12.40	16.82
		310	12.40	17.19
		349	12.41	17.10
Scenario 8	New Traffic Flows, Taxiway Addition, LROP Segregated & LRBS Closed	155	13.58	
		233	13.58	
		310	13.70	
		349	13.66	

6.1.4 RUNWAY 08 LROP / 07 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - DIAGRAMS

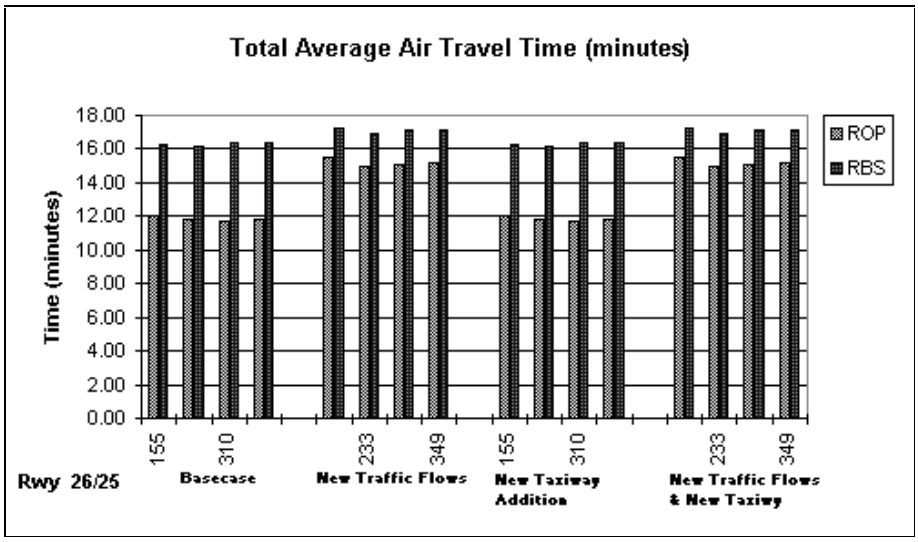


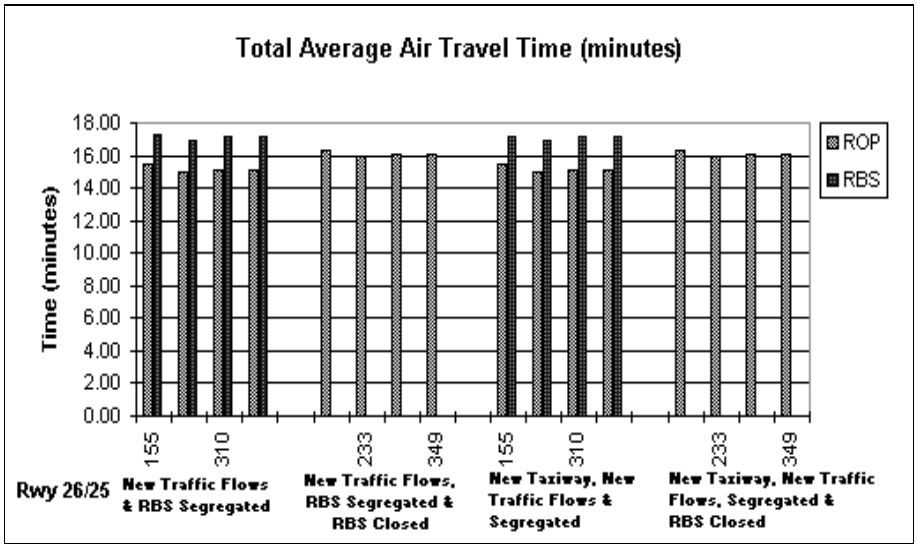


6.1.5 RUNWAY 26 LROP / 25 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - TABLE

			Average Air Travel (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	12.07	16.29
		233	11.79	16.12
		310	11.72	16.34
		349	11.80	16.32
Scenario 2	New Traffic Flows	155	15.50	17.22
		233	14.99	16.96
		310	15.10	17.12
		349	15.15	17.14
Scenario 3	Taxiway Addition LROP	155	12.07	16.29
		233	11.79	16.12
		310	11.72	16.34
		349	11.80	16.32
Scenario 4	New Traffic Flows & Taxiway Addition	155	15.50	17.22
		233	14.99	16.96
		310	15.09	17.14
		349	15.15	17.14
Scenario 5	New Traffic Flows & LROP Segregated	155	15.50	17.22
		233	14.99	16.96
		310	15.10	17.12
		349	15.15	17.14
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	155	16.31	
		233	15.89	
		310	16.09	
		349	16.11	
Scenario 7	New Traffic Flows, Taxiway Addition & LROP Segregated	155	15.52	17.12
		233	15.00	16.90
		310	15.10	17.12
		349	15.15	17.14
Scenario 8	New Traffic Flows, Taxiway Addition, LROP Segregated & LRBS Closed	155	16.31	
		233	15.89	
		310	16.09	
		349	16.11	

6.1.6 RUNWAY 26 LROP / 25 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - DIAGRAMS





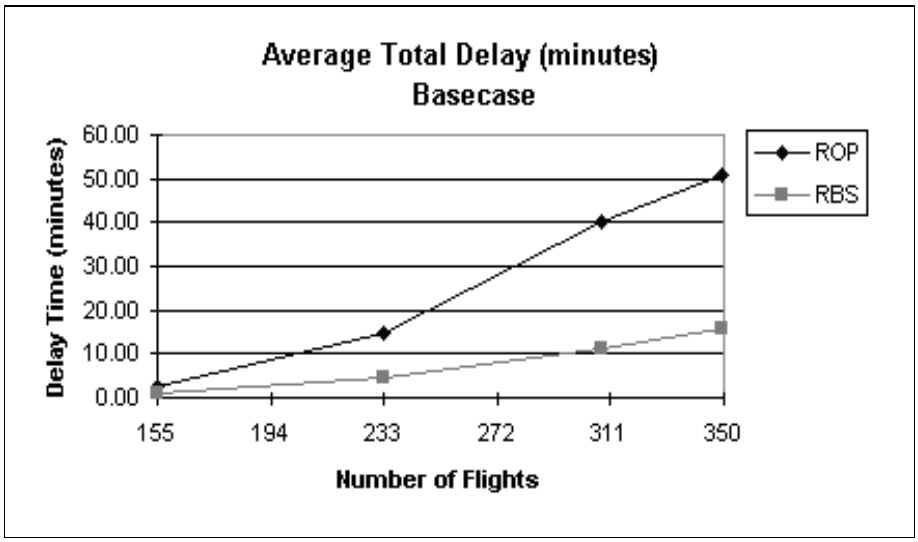
6.2 OVER THE CITY

6.2.1 RUNWAY 08 LROP / 07 LRBS - AVERAGE TOTAL DELAY (MINUTES) - TABLE

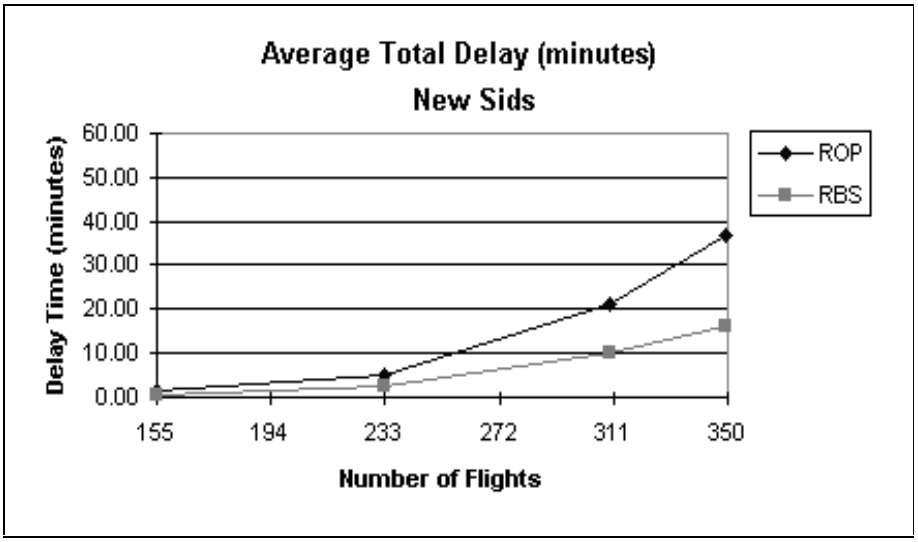
			Average Total Delay (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	2.38	1.16
		233	14.67	4.37
		308	40.20	11.22
		349	50.78	15.64
Scenario 2	New Traffic Flows	155	1.75	0.70
		233	5.28	2.52
		310	21.10	10.11
		349	36.88	16.08
Scenario 3	Taxiway Addition at	155	0.65	0.55
	LROP	233	2.04	1.79
		310	4.85	5.13
		349	7.57	9.01
Scenario 4	Taxiway Addition&	155	0.28	0.46
	New Traffic Flows	233	0.54	1.69
		310	1.34	5.20
		349	1.89	7.93
Scenario 5	New Traffic Flows &	155	0.70	0.70
	LROP Segregated	233	1.68	2.52
		310	2.92	10.11
		349	4.24	16.10
Scenario 6	New Traffic Flows,	155	2.12	
	LROP Segregated &	233	6.19	
	LRBS Closed	310	14.88	
		349	29.76	
Scenario 7	Taxiway Addition,	155	0.22	0.46
	New Traffic Flows &	233	0.40	1.69
	LROP Segregated	310	0.73	5.20
		349	1.01	7.93
Scenario 8	Taxiway Addition,	155	0.44	
	New Traffic Flows,	233	1.01	
	LROP Segregated &	310	1.81	
	LRBS Closed	349	2.69	

6.2.2 RUNWAY 08 LROP / 07 LRBS - AVERAGE TOTAL DELAY (MINUTES) - DIAGRAMS

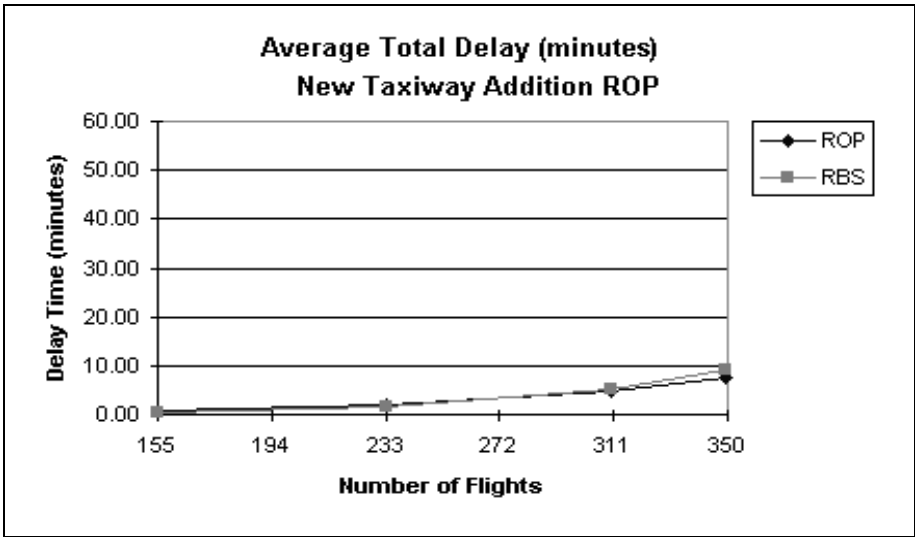
6.2.2.1 SCENARIO ONE: BASECASE



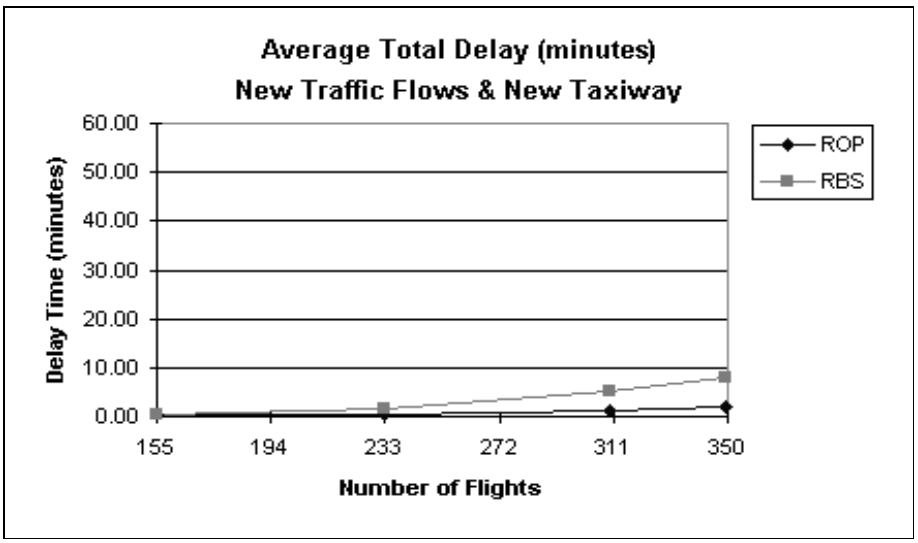
6.2.2.2 SCENARIO TWO: NEW TRAFFIC FLOWS



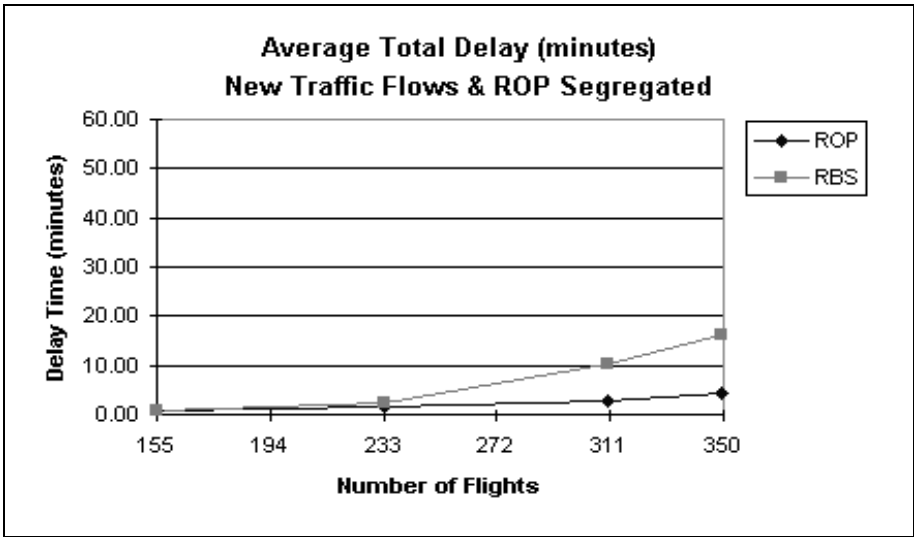
6.2.2.3 SCENARIO THREE: NEW TAXIWAY ADDTION AT LROP



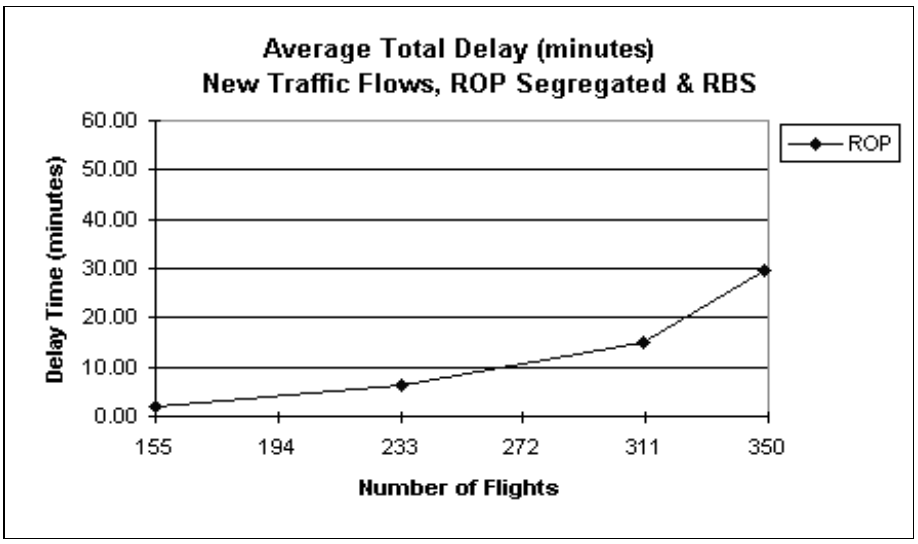
6.2.2.4 SCENARIO FOUR: NEW TRAFFIC FLOWS AND NEW TAXIWAY



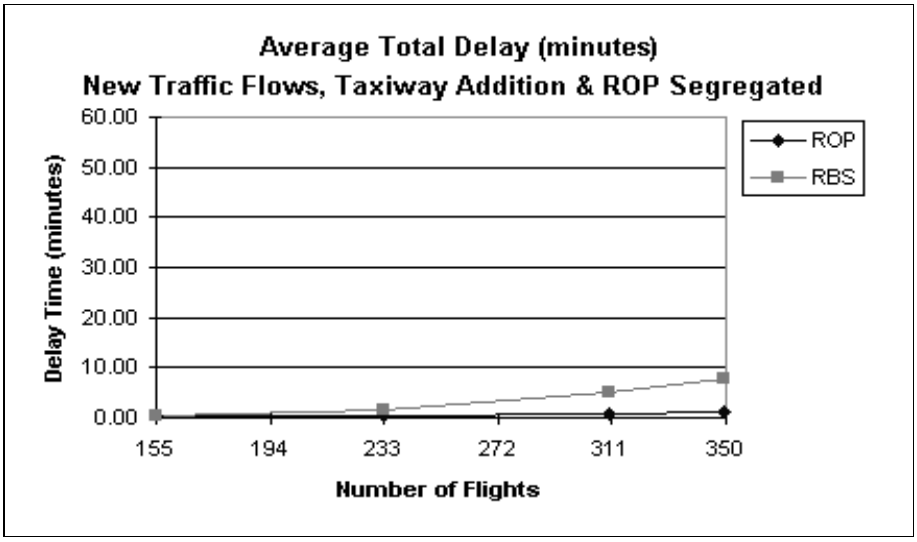
6.2.2.5 SCENARIO FIVE: NEW TRAFFIC FLOWS AND LROP SEGREGATED



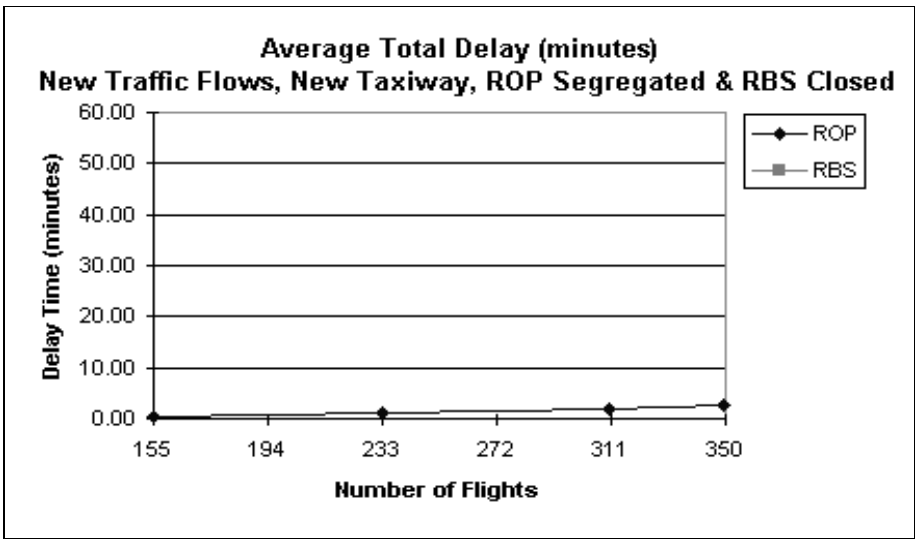
6.2.2.6 SCENARIO SIX: NEW TRAFFIC FLOWS, TAXIWAY ADDITION & LROP SEGREGATED



6.2.2.7 SCENARIO SEVEN: NEW TRAFFIC FLOWS, TAXIWAY ADDITION, LROP SEGREGATED



6.2.2.8 SCENARIO EIGHT: NEW TRAFFIC FLOWS, TAXIWAY ADDITION, LROP SEGREGATED AND LRBS CLOSED

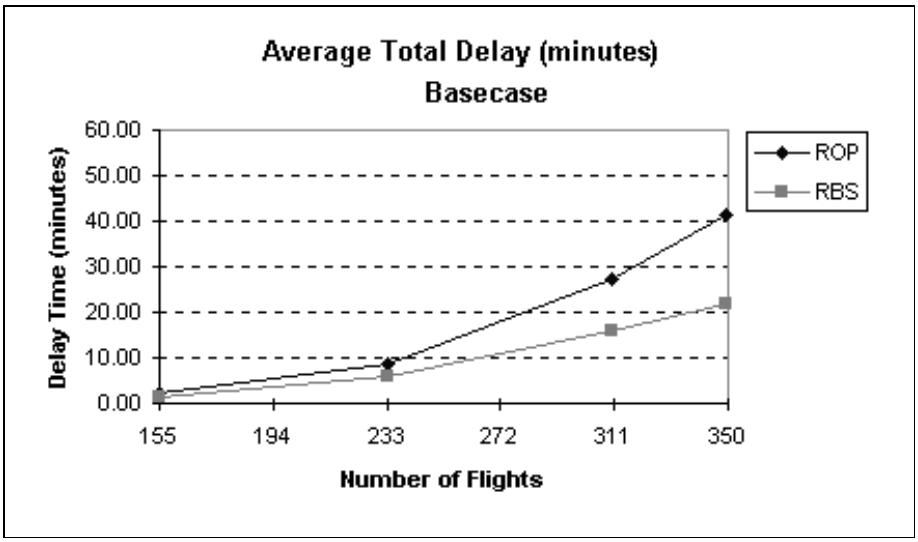


6.2.3 RUNWAY 26 LROP / 25 LRBS - AVERAGE TOTAL DELAY (MINUTES) - TABLE

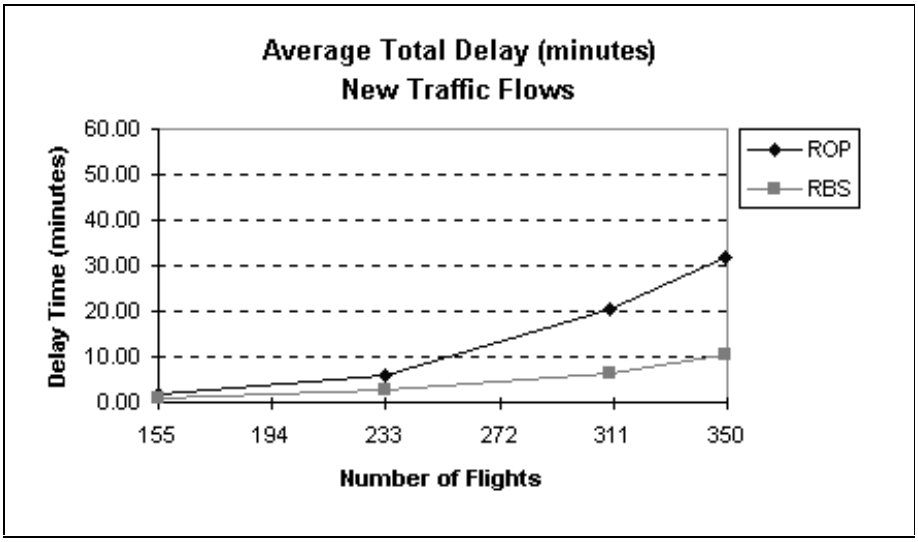
			Average Total Delay (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	2.37	1.44
		233	8.78	6.05
		310	27.07	15.81
		349	41.59	21.91
Scenario 2	New Traffic Flows	155	1.77	0.70
		233	6.02	2.70
		310	20.29	6.50
		349	31.70	10.35
Scenario 3	Taxiway Addition at LROP	155	0.93	1.04
		233	3.46	2.90
		310	7.48	8.31
		349	12.37	12.15
Scenario 4	Taxiway Addition& New Traffic Flows	155	0.40	0.53
		233	0.73	1.81
		310	1.57	4.48
		349	1.91	6.99
Scenario 5	New Traffic Flows & LROP Segregated	155	0.60	0.70
		233	2.17	2.70
		310	4.29	6.49
		349	6.15	10.86
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	155	1.10	
		233	9.55	
		310	18.29	
		349	23.86	
Scenario 7	Taxiway Addition, New Traffic Flows & LROP Segregated	155	0.26	0.55
		233	0.42	1.80
		310	0.70	4.41
		349	0.87	6.99
Scenario 8	Taxiway Addition, New Traffic Flows, LROP Segregated & LRBS Closed	155	0.49	
		233	0.95	
		310	1.29	
		349	2.33	

6.2.4 RUNWAY 26 LROP / 25 LRBS - AVERAGE TOTAL DELAY (MINUTES) - DIAGRAMS

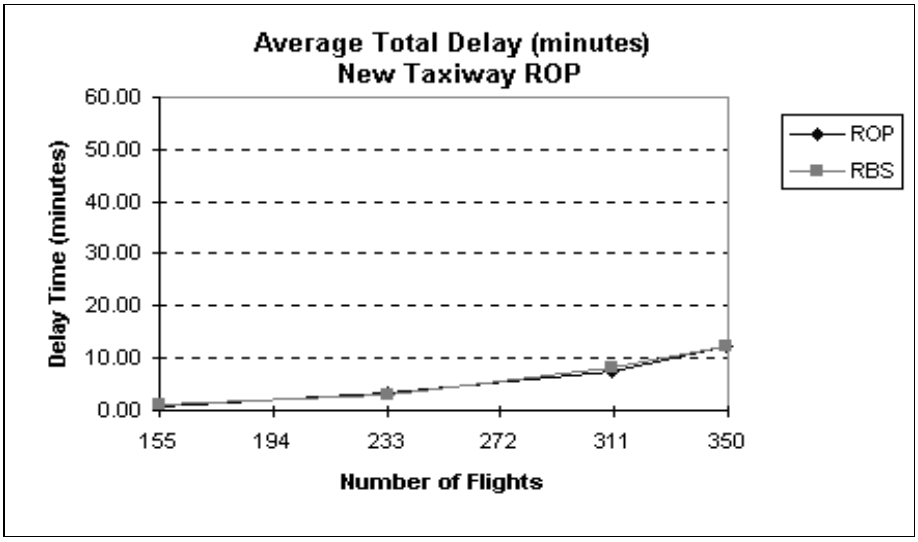
6.2.4.1 SCENARIO ONE: BASECASE



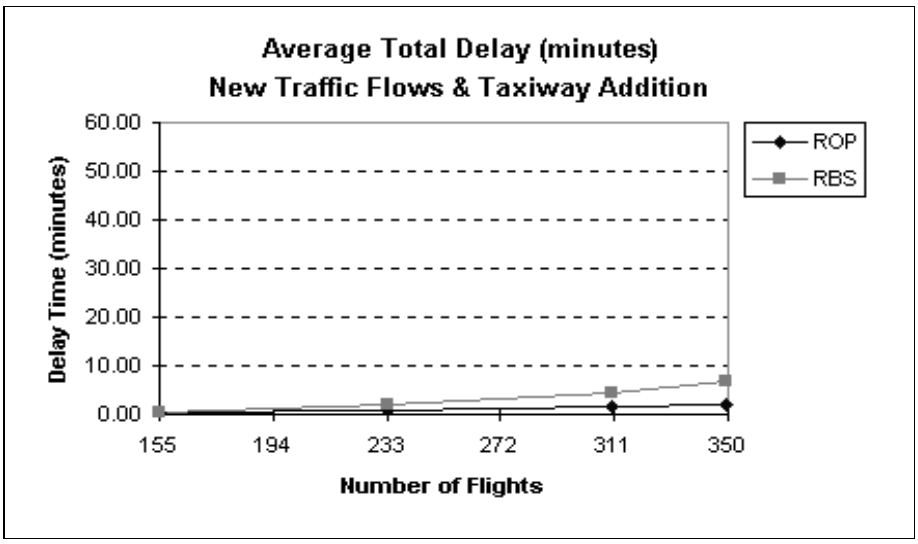
6.2.4.2 SCENARIO TWO: NEW TRAFFIC FLOWS



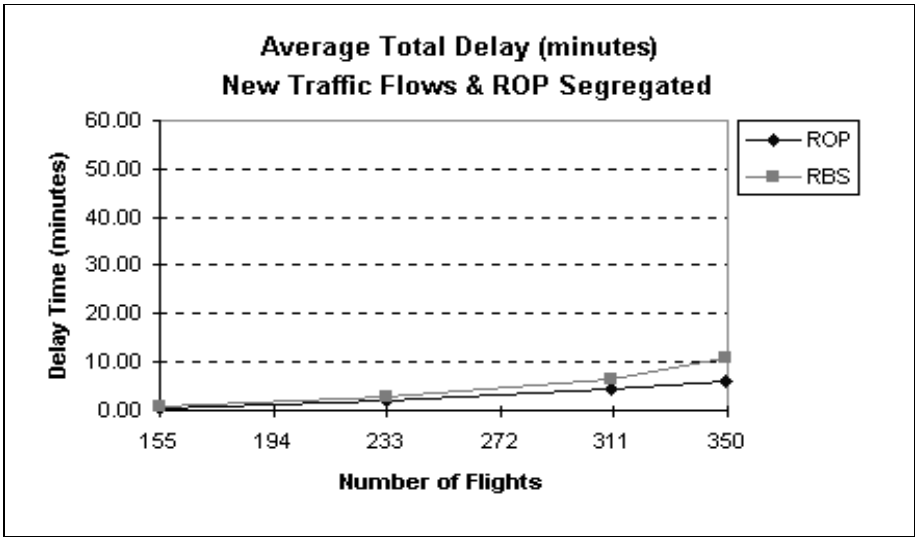
6.2.4.3 SCENARIO THREE: NEW TAXIWAY ADDITION AT LROP



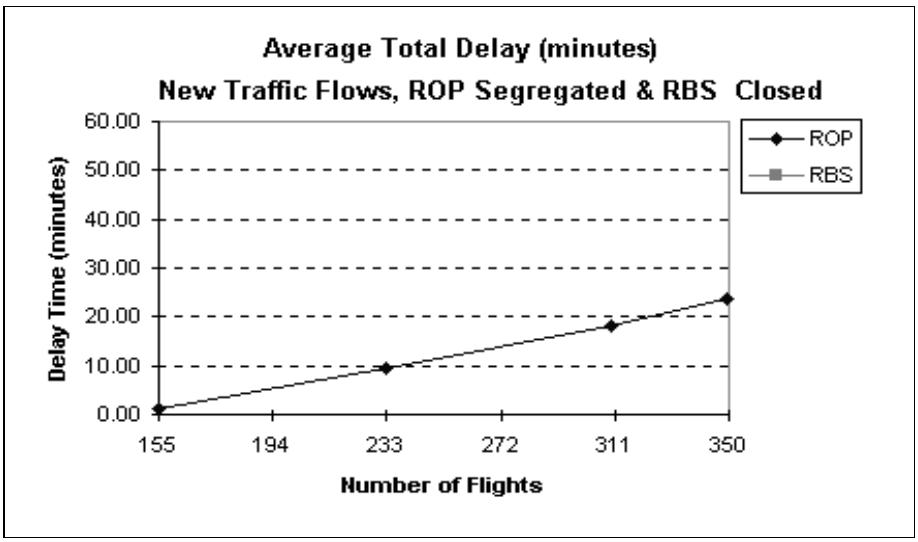
6.2.4.4 SCENARIO FOUR: NEW TRAFFIC FLOWS AND TAXIWAY ADDITION



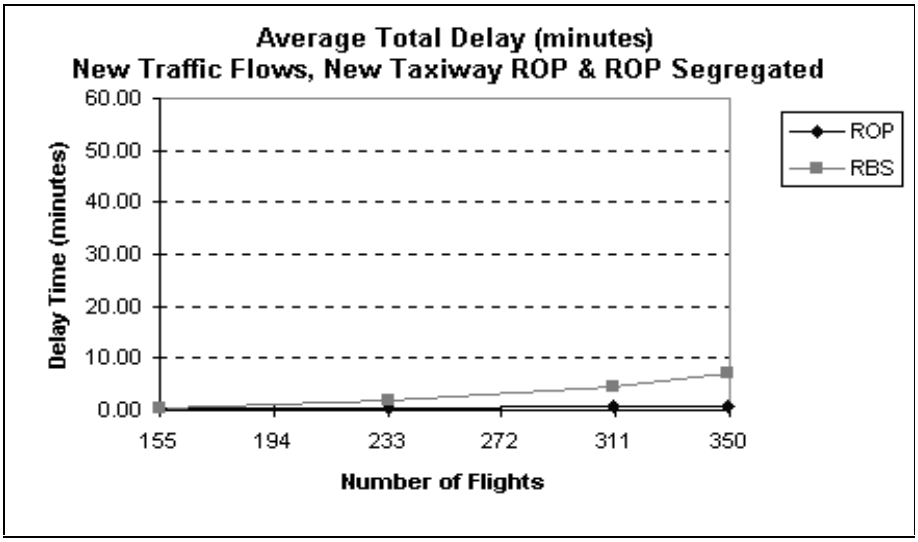
6.2.4.5 SCENARIO FIVE: NEW TRAFFIC FLOWS & LROP SEGREGATED



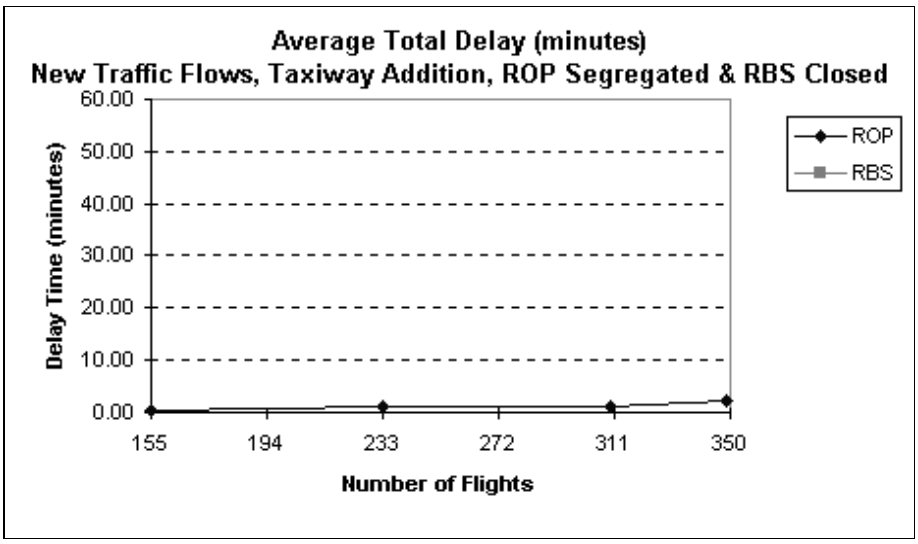
6.2.4.6 SCENARIO SIX: NEW TRAFFIC FLOWS, LROP SEGREGATED & LRBS CLOSED



6.2.4.7 SCENARIO SEVEN: NEW TRAFFIC FLOWS, TAXIWAY ADDITION, LROP SEGREGATED



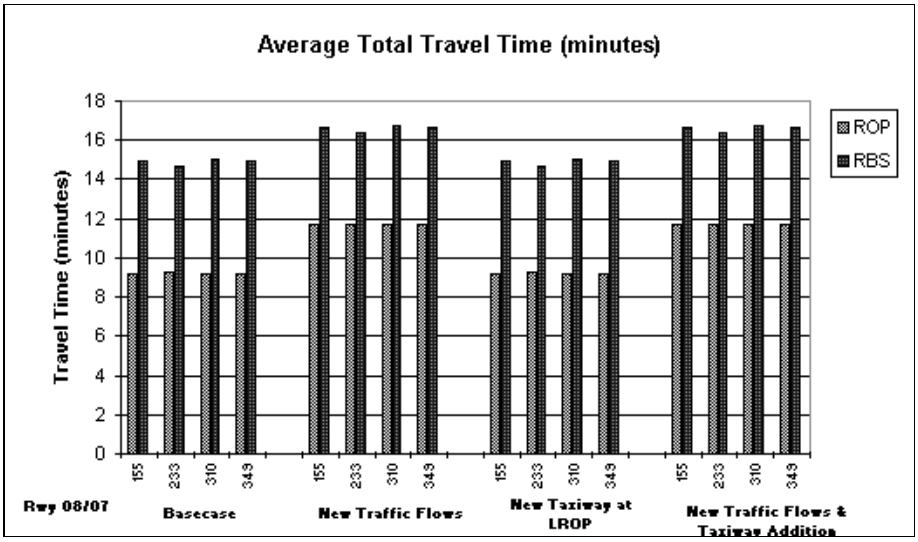
6.2.4.8 SCENARIO EIGHT: NEW TRAFFIC FLOWS, TAXIWAY ADDITION, LROP SEGREGATED & LRBS CLOSED

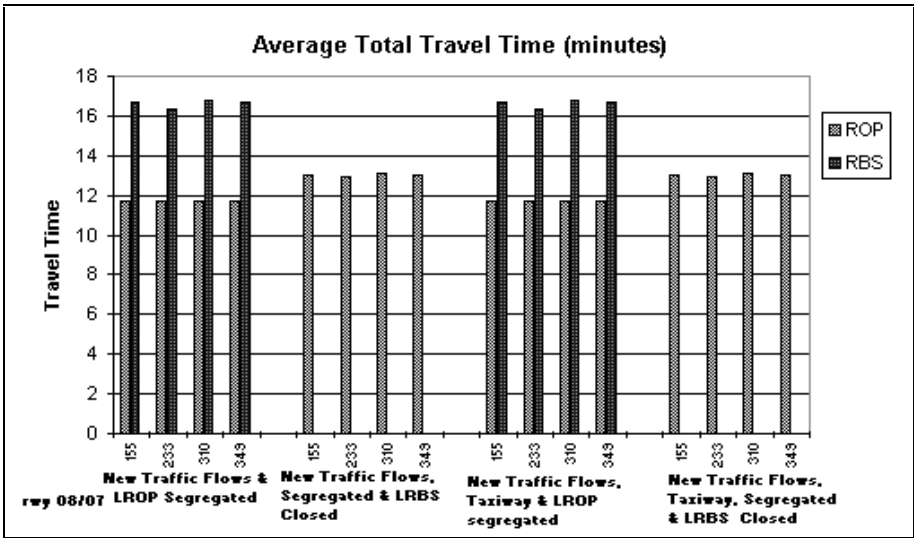


6.2.5 RUNWAY 08 LROP / 07 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - TABLE

			Average Air Travel (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	9.19	14.92
		233	9.30	14.67
		310	9.16	15.01
		349	9.17	14.98
Scenario 2	New Traffic Flows	155	11.70	16.68
		233	11.69	16.38
		310	11.69	16.76
		349	11.70	16.68
Scenario 3	Taxiway Addition at LROP	155	9.19	14.92
		233	9.30	14.67
		310	9.16	15.01
		349	9.17	14.98
Scenario 4	Taxiway Addition& New Traffic Flows	155	11.70	16.68
		233	11.69	16.38
		310	11.69	16.76
		349	11.70	16.68
Scenario 5	New Traffic Flows & LROP Segregated	155	11.70	16.68
		233	11.69	16.38
		310	11.69	16.76
		349	11.70	16.68
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	155	13.00	
		233	12.96	
		310	13.10	
		349	13.05	
Scenario 7	Taxiway Addition, New Traffic Flows & LROP Segregated	155	11.70	16.68
		233	11.69	16.38
		310	11.69	16.76
		349	11.70	16.68
Scenario 8	Taxiway Addition, New Traffic Flows, LROP Segregated & LRBS Closed	155	13.00	
		233	12.96	
		310	13.10	
		349	13.05	

6.2.6 RUNWAY 08 LROP / 07 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - DIAGRAMS

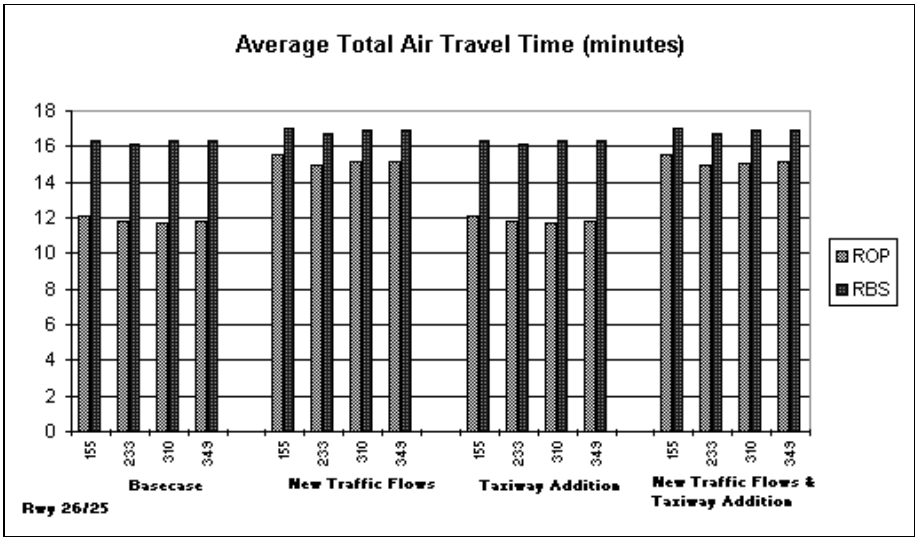


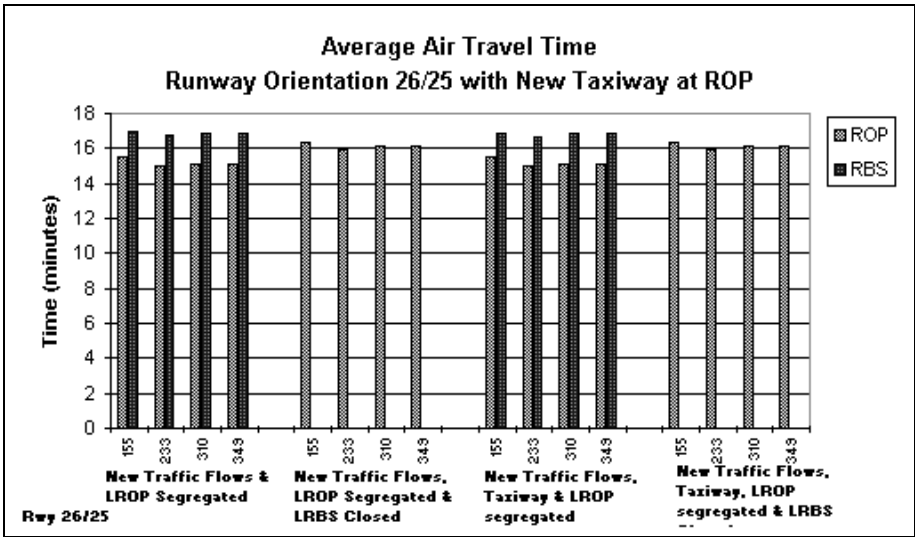


6.2.7 RUNWAY 26 LROP / 25 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - TABLE

			Average Air Travel (min)	
		Flights	ROP	RBS
Scenario 1	Basecase	155	12.068269	16.293931
		233	11.793867	16.12002
		310	11.717558	16.335609
		349	11.797738	16.318586
Scenario 2	New Traffic Flows	155	15.498676	16.979118
		233	14.99543	16.732382
		310	15.102377	16.888725
		349	15.148256	16.89767
Scenario 3	Taxiway Addition at LROP	155	12.068285	16.293585
		233	11.793504	16.119981
		310	11.717045	16.335508
		349	11.797604	16.317686
Scenario 4	Taxiway Addition& New Traffic Flows	155	15.498676	16.979338
		233	14.995429	16.733196
		310	15.090101	16.895228
		349	15.148407	16.898626
Scenario 5	New Traffic Flows & LROP Segregated	155	15.498676	16.979118
		233	14.99543	16.732382
		310	15.102386	16.888725
		349	15.148293	16.897721
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	155	16.302701	
		233	15.88303	
		310	16.087553	
		349	16.108959	
Scenario 7	Taxiway Addition, New Traffic Flows & LROP Segregated	155	15.522316	16.884938
		233	15.00478	16.67979
		310	15.102212	16.889841
		349	15.148392	16.898626
Scenario 8	Taxiway Addition, New Traffic Flows, LROP Segregated & LRBS Closed	155	16.31	
		233	15.89	
		310	16.09	
		349	16.11	

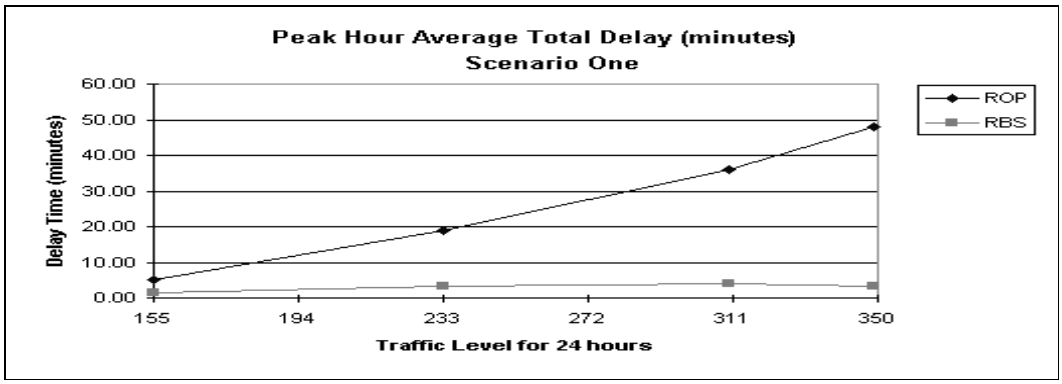
6.2.8 RUNWAY 26 LROP / 25 LRBS - AVERAGE AIR TRAVEL TIME (MINUTES) - DIAGRAMS

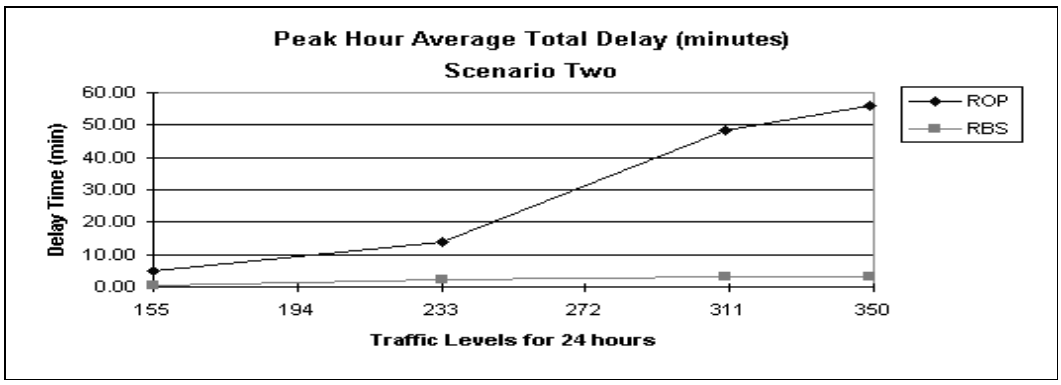


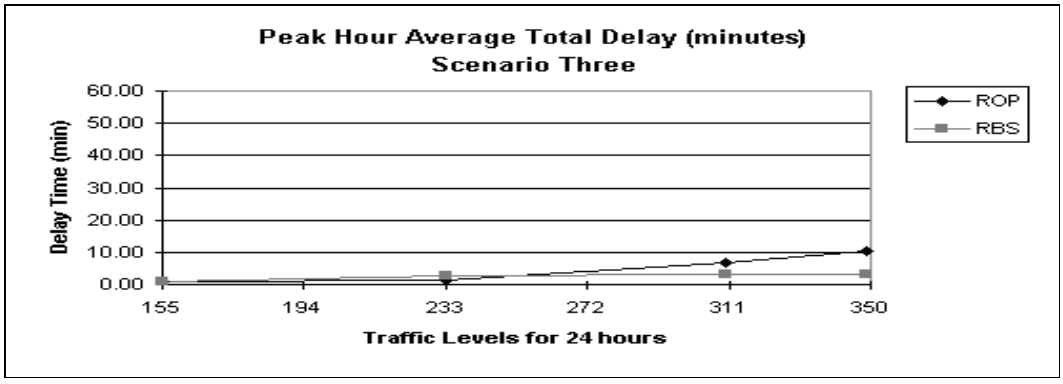


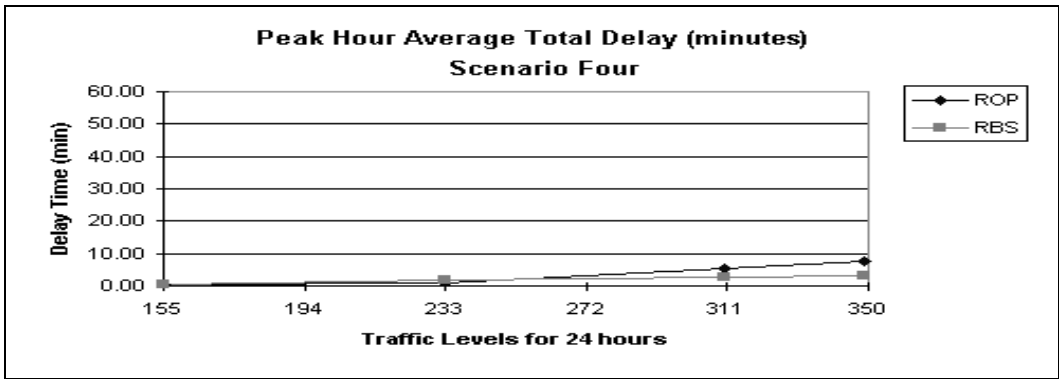
6.3 PEAK HOUR - AVOIDING THE CITY - RUNWAY 08/07 - DIAGRAMS

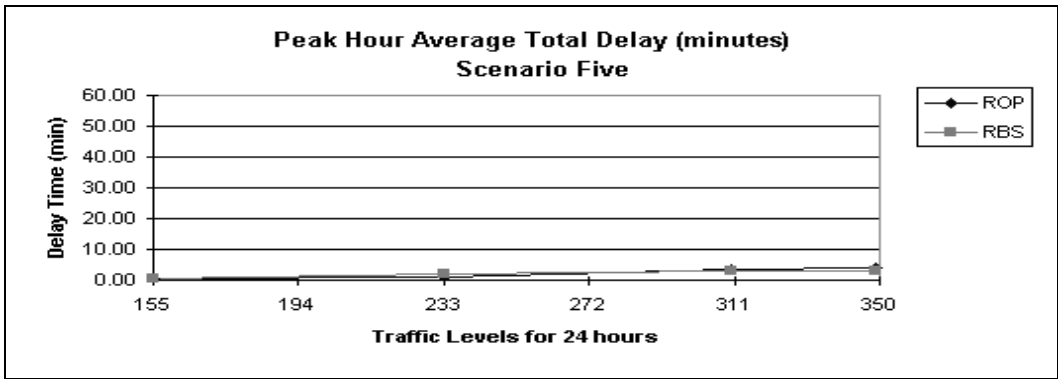
The peak hour, for the Bucharest TMA, was found to be from 14h00 to 15h00 (see 1.4.2 Traffic Samples page 2). The delay values for the traffic in this peak hour are illustrated in the diagrams below (pages 21 to 25), the tables can be found on pages 26 and 27.

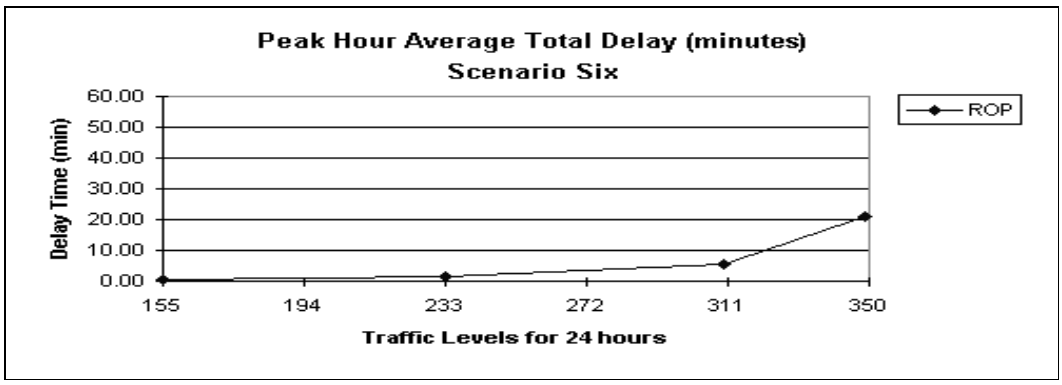


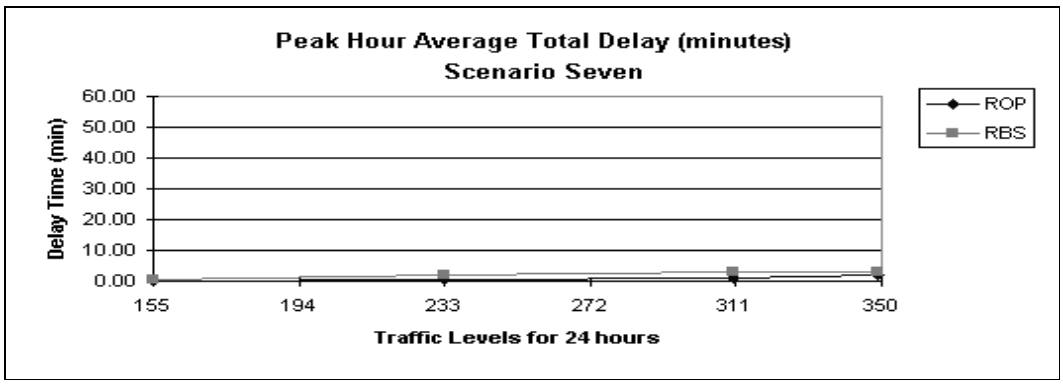


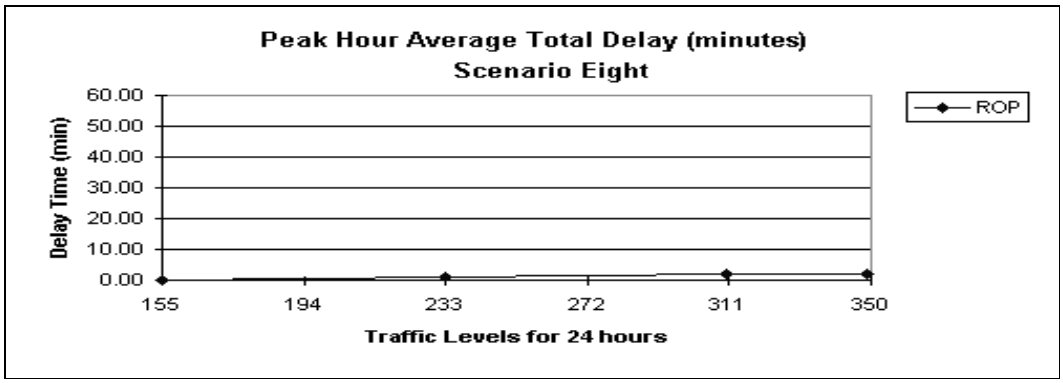



Peak Hour Average Total Delay (minutes)
Scenario Four
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP
RBS


Peak Hour Average Total Delay (minutes)
Scenario Five
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP
RBS


Peak Hour Average Total Delay (minutes)
Scenario Six
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP

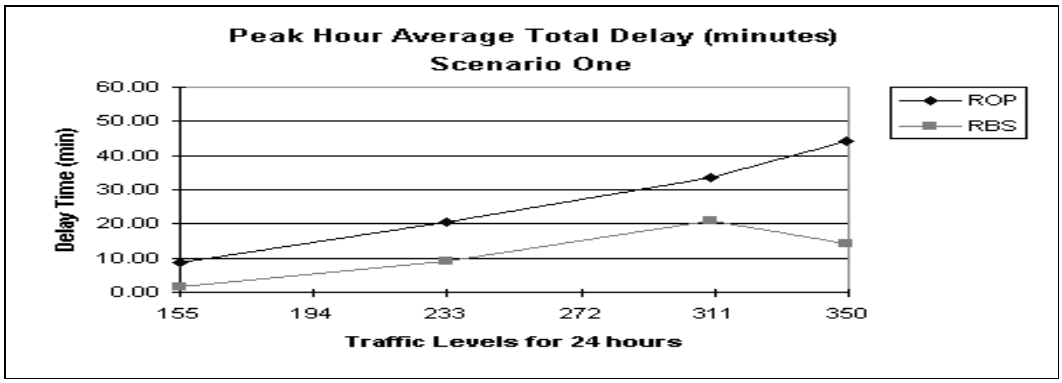

Peak Hour Average Total Delay (minutes)
Scenario Seven
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP
RBS

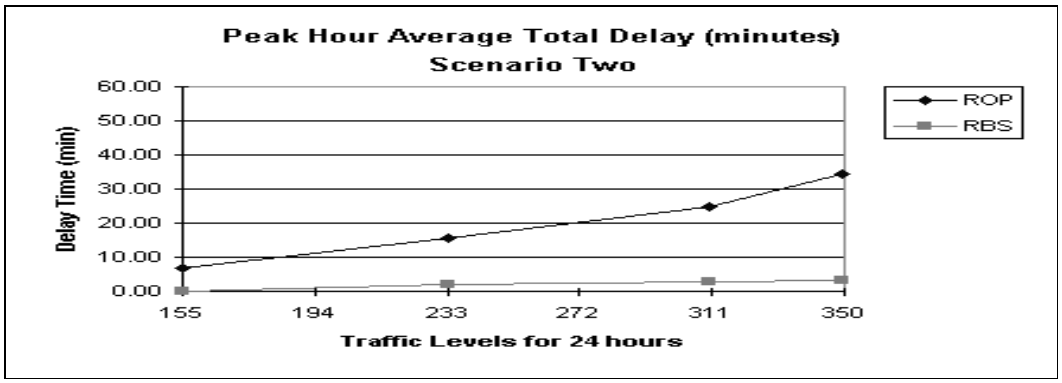


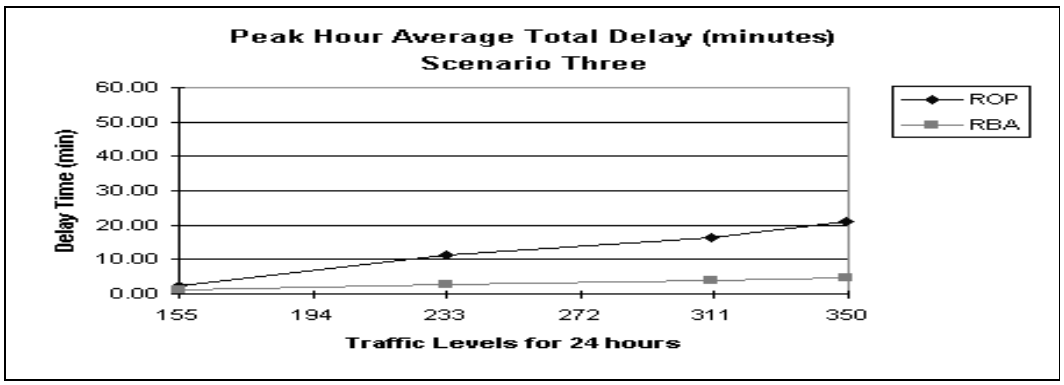
6.4 PEAK HOUR - AVOIDING THE CITY - RUNWAY 08/07 - TABLE

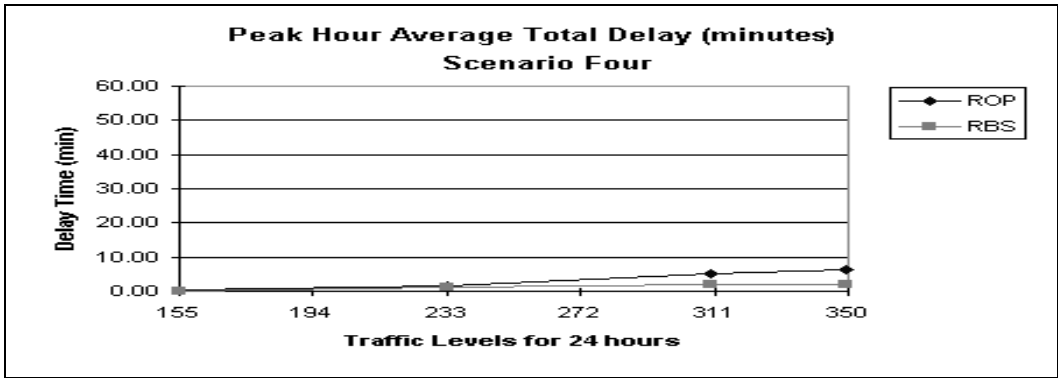
		ROP Flights	RBS Flights	Total Flights	Total Average Delay	
					ROP	RBS
Scenario 1	Basecase	12	3	155	5.23	1.29
		12	6	233	18.85	3.19
		10	6	310	36.03	3.87
		11	6	349	48.15	3.22
Scenario 2	New Traffic Flows	12	3	155	5.03	0.66
		18	7	233	13.81	2.19
		15	7	310	48.36	3.13
		14	7	349	56.06	3.22
Scenario 3	Taxiway Addition LROP	11	3	155	0.73	1.00
		16	7	233	1.45	2.69
		23	7	310	6.81	2.98
		23	7	349	10.28	3.21
Scenario 4	New Traffic Flows & Taxiway Addition	11	3	155	0.36	0.66
		16	7	233	0.88	1.92
		23	7	310	5.22	2.78
		27	8	349	7.55	2.92
Scenario 5	New Traffic Flows & LROP Segregated	11	3	155	0.53	0.66
		16	7	233	1.02	2.19
		23	7	310	3.32	3.13
		27	7	349	4.18	3.22
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	14		155	0.59	
		23		233	1.74	
		33		310	5.54	
		38		349	20.90	
Scenario 7	New Traffic Flows, Taxiway Addition & LROP Segregated	11	3	155	0.18	0.66
		16	7	233	0.50	1.92
		23	7	310	1.23	2.78
		27	8	349	1.84	2.92
Scenario 8	New Traffic Flows, Taxiway Addition, LROP Segregated & LRBS Closed	14		155	0.23	
		23		233	0.83	
		32		310	1.76	
		36		349	2.21	

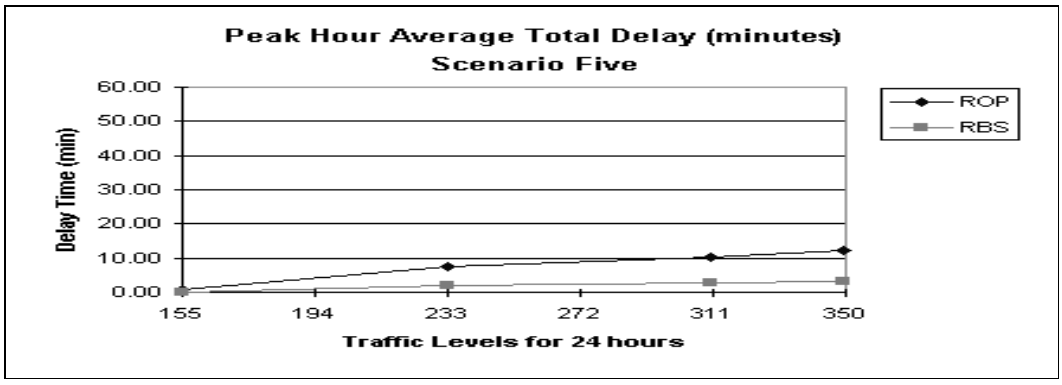
6.5 PEAK HOUR - AVOIDING THE CITY - RUNWAY 26/25 - DIAGRAMS

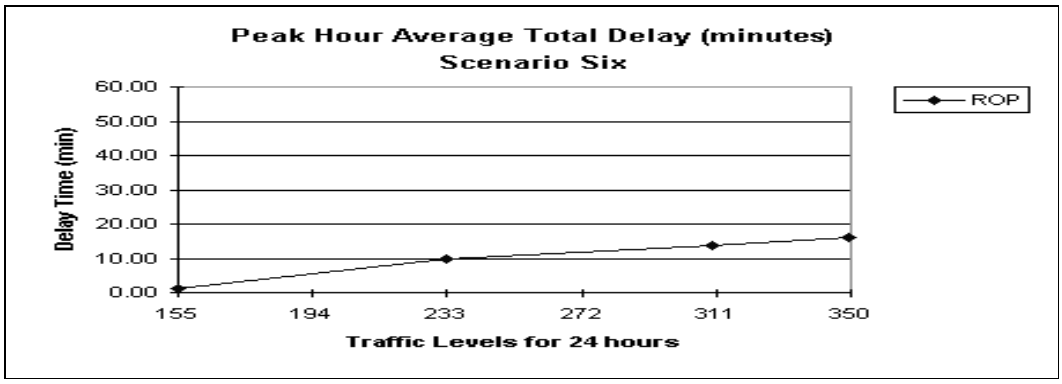


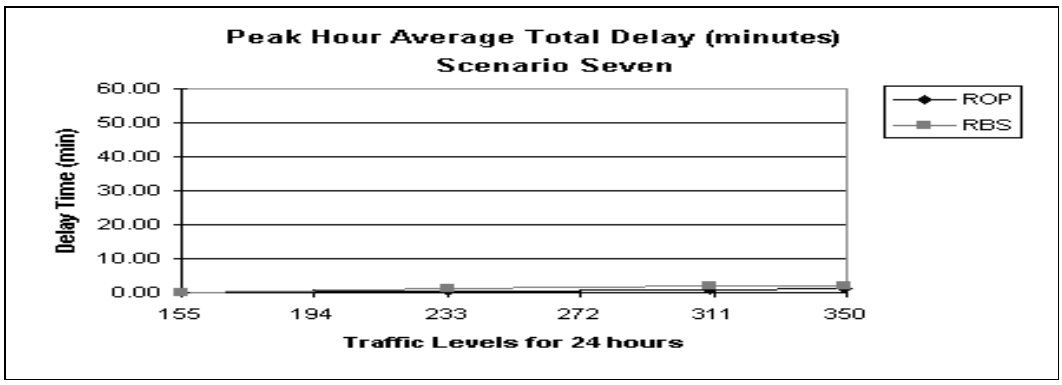


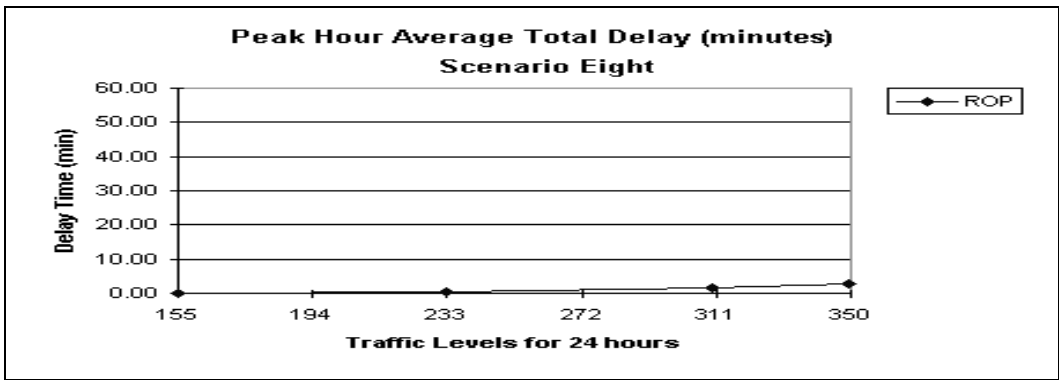





Peak Hour Average Total Delay (minutes)
Scenario Five
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP
RBS


Peak Hour Average Total Delay (minutes)
Scenario Six
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP


Peak Hour Average Total Delay (minutes)
Scenario Seven
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP
RBS


Peak Hour Average Total Delay (minutes)
Scenario Eight
Delay Time (min)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
155
194
233
272
311
350
Traffic Levels for 24 hours
ROP

6.6 PEAK HOUR - AVOIDING THE CITY - RUNWAY 26/25 - TABLE

		ROP flights	RBS flights	Total Traffic	Average Total Delay	
					ROP	RBS
Scenario 1	Basecase	12	2	155	8.51	1.76
		13	5	233	20.51	8.90
		14	6	310	33.64	20.99
		14	6	349	44.35	14.28
Scenario 2	New Traffic Flows	12	2	155	6.66	0.02
		14	5	233	15.49	1.88
		15	7	310	24.72	2.91
		15	6	349	34.40	3.19
Scenario 3	Taxiway Addition LROP	12	2	155	2.42	1.16
		15	5	233	11.49	2.77
		18	6	310	16.48	3.84
		18	6	349	21.11	4.52
Scenario 4	New Traffic Flows & Taxiway Addition	12	2	155	0.59	0.02
		18	5	233	1.52	1.10
		24	7	310	5.18	1.93
		28	6	349	6.29	1.83
Scenario 5	New Traffic Flows & LROP Segregated	12	2	155	0.85	0.02
		17	5	233	7.34	1.88
		20	7	310	10.41	2.91
		21	6	349	12.30	3.19
Scenario 6	New Traffic Flows, LROP Segregated & LRBS Closed	14		155	1.31	
		17		233	9.85	
		20		310	13.75	
		21		349	16.25	
Scenario 7	New Traffic Flows, Taxiway Addition & LROP Segregated	12	2	155	0.15	0.02
		18	5	233	0.33	1.10
		24	7	310	0.84	1.93
		28	6	349	1.24	1.83
Scenario 8	New Traffic Flows, Taxiway Addition, LROP Segregated & LRBS Closed	14		155	0.15	
		23		233	0.47	
		32		310	1.59	
		35		349	2.73	