Second opinion on the application of CDAs at Schiphol Airport

Final report

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Document information

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Summary and conclusions

Background

A concept for continuous descent approaches (CDAs) based on fixed routes and area navigation (RNAV) has been proposed by LVNL for implementation at Amsterdam Schiphol airport (AMS). This concept has, as a pre-requisite, the requirement to use two arrivals runways throughout the day including those periods between arrivals peaks where currently only one arrivals runway is in use. The use of the second runway during the day is considered necessary for development activities that would enable RNAV CDAs, similar to those currently only being operated between 23:00 and 06:00, to be extended step-by-step into the daytime. The LVNL view is that high density RNAV CDAs cannot be introduced at AMS prior to 2020. Limited implementation of RNAV CDAs may be possible earlier during periods of lower traffic density.

Residents groups from the area surrounding AMS have questioned the LVNL proposal and requested a second opinion on it, particularly on the necessity of using a second arrivals runway during non-peak times, as well as an assessment whether other techniques could be used to ameliorate noise nuisance at AMS prior to 2020 through application of CDAs.

This report has been produced by Helios in response to this request for a second opinion. This second opinion has been made in the European and global context for CDAs expressed in the EUROCONTROL implementation guidance[1] that is currently being used as input for the development of an International Civil Aviation Organisation (ICAO) standard. The report is based on Helios' best judgement using the information available at the time.

The assessment recognises the following periods during the day:

- Arrivals peaks, divided into two morning peaks, two afternoon peaks and one evening peak.
- Outside arrivals peaks, covering the period directly following a peak, i.e. two morning periods, two afternoon periods and one evening period.
- Night time (23:00-06:00).

Assessment of the LVNL concept

The LVNL concept is based on a specific definition of CDA based on fixed routes, which is much more prescriptive than the broad EUROCONTROL definition. The impact of this will be to concentrate aircraft noise along the fixed routes but with the consequence of adding aircraft noise to a second runway which would not currently be used outside arrival peak periods. Use of RNAV and fixed routes is in line with the long term strategy of LVNL and with international developments.

Using existing procedures and technology, the LVNL concept cannot currently provide sufficient capacity to enable RNAV CDAs either a) onto two runways during peak periods or b) onto a single runway outside arrival peak periods during the morning and afternoon even if holding techniques such as stacks are used. In the latter case, very high holding times and air traffic flow management delays are likely to be introduced. In the future, procedures such as Point Merge and support tools and technologies such as SARA (Speed And Route Advisor) and SafeRoute (ASAS), possibly in combination with increased experience with RNAV CDA operations, are expected to increase the achievement rate of RNAV CDA and this conclusion

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[1] 'Continuous Descent Approach Implementation Guidance Material', EUROCONTROL, May 2008, www.EUROCONTROL.int/environment/gallery/content/public/documents/cda_brochureA4_may08_web.pdf

would need to be revisited. It is not expected that such developments will deliver the capacity needed to enable RNAV CDA during busy periods until the timeframe of at least 2020. Clearly, however, short- and medium-term pragmatic solutions must not distract from the need for these longer term developments as they are expected to eventually bring significant benefits.

However, the RNAV CDA concept does appear to provide sufficient capacity on a single runway in the evening to extend the use of RNAV CDAs from 23:00 to 06:00 as at present step-by-step to eventually cover the period from the last evening arrivals peak until 06:30 in the morning, possibly stretching until 07:00 if demand management techniques such as the use of stacks and/or trombones were applied (which will have a negative impact on noise concentration), or scheduling limits were applied to restrict traffic growth at the edges of the night-time period. The boundaries of this period would need to be applied tactically on a day-by-day basis to account for the prevailing traffic situation, especially in the cases that the evening arrivals peak is extended due to knock-on effects of delays during the day and in managing variations in the time of the early morning arrivals peak. It is important to note though that new RNAV routes and procedures would need to be developed for this extension into evening and possibly early morning, as the procedures currently used during the night can not be applied outside the 23:00-06:00 period[2]. The step-by-step introduction of RNAV CDA in the evening could be started in the near future subject to the necessary procedures, safety cases and air traffic control operations being approved, but achieving operational use during the full evening period (and eventually parts of the rest of the day) will take considerable time.

Possible alternative concepts

There is an alternative CDA concept based on vectoring aircraft to maintain their separation along the approach path, in a similar way to the way aircraft are vectored along their stepped approach paths at present. This technique – termed tactical CDA – does not reduce capacity to the same degree as the RNAV CDA technique and may possibly be implemented on a shorter timescale than RNAV CDAs (although such implementation is still likely to take several years). Tactical CDAs are likely to provide sufficient capacity to allow their use onto a single runway in the afternoon outside of the peak arrivals periods without the need for significant airborne holding.

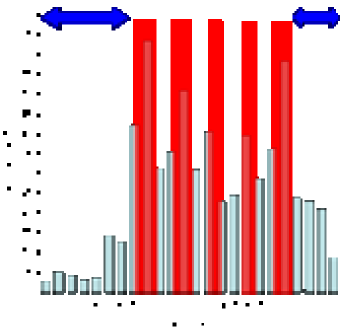
In addition, the tactical CDA could provide sufficient capacity to allow CDAs to be operated into the two arrivals runways that are active in the afternoon arrivals peaks, again without any significant airborne holding or delays. Noise dispersion would be as at present as vectoring techniques are currently used. However, the relationship between demand, capacity and delays derived from Heathrow, where airborne holding, speed control and vectoring are applied, indicates that conservative estimates of the potential reduction of capacity that might result from the tactical CDA technique during the morning arrivals peaks and the evening arrivals peak is likely to introduce significant delays, both air traffic flow management and airborne holding. The other effect of application of tactical CDAs is that noise is dispersed across the approach path rather than being concentrated along a single track.

Conclusions

The conclusions based on the information available can be summarised as:

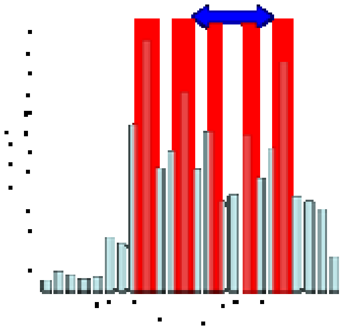
[2] It is even likely that any new RNAV procedures to be developed for the evening period would also replace the current night procedures so that a single set of procedures can be applied in evening and night. This seems preferable over separate sets of procedures for evening and night, which would make the operational situation more complex.

Evening and night



- Subject to the necessary approvals and changes to air traffic control operations, it appears that **RNAV CDA** can provide sufficient capacity on a single runway to cover the period from the last arrivals peak in the evening to 06:30 in the short-term[3] (and possibly to cover the period up to 07:00 if demand management techniques - airborne holding or schedule limits - are acceptable). The application of the technique would need to be managed tactically rather than being rigidly applied to account for traffic variations at the beginning and at the end of the period. Risk of knock-on effects from any disruptions in the early morning should also be considered in this.

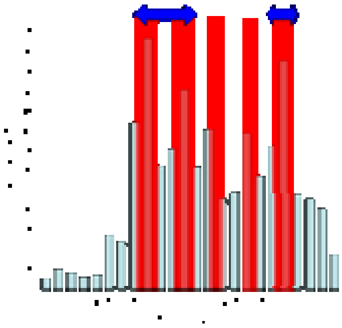
Daytime outside morning and evening arrivals peaks



- Using current procedures and technology, the evidence suggests that RNAV CDA cannot be applied during the day continuously either on two runways during afternoon peak periods or on a single runway outside arrival peak periods without a major negative impact on capacity and delays. Due to the complexity of operations at Schiphol, ad-hoc application on a tactical basis for limited periods is not likely to be possible.
- A second arrivals runway, with the associated noise nuisance, would be needed to enable RNAV CDA outside of peak arrivals periods in the afternoon. Major procedural and/or technology development is needed to enhance the achievement rate of the RNAV CDA in order to provide sufficient capacity on a single runway to meet current demand levels outside arrival peak periods.
- For day-time operations, assuming that the necessary procedures and safety cases are developed and air traffic control operations are adapted appropriately, **tactical CDA** provides an alternative technique to RNAV CDA for all periods between the morning and evening arrivals peaks. This would not lead to a reduction of current noise dispersion but would have a positive impact on noise volume. Application of this technique would prevent LVNL's proposals to use a second arrivals runway to develop and test the procedures and technology needed to implement RNAV CDA in the future. These test and development activities would have to take place at other times, e.g. at night on a single runway, or on an ad hoc basis during the daytime.

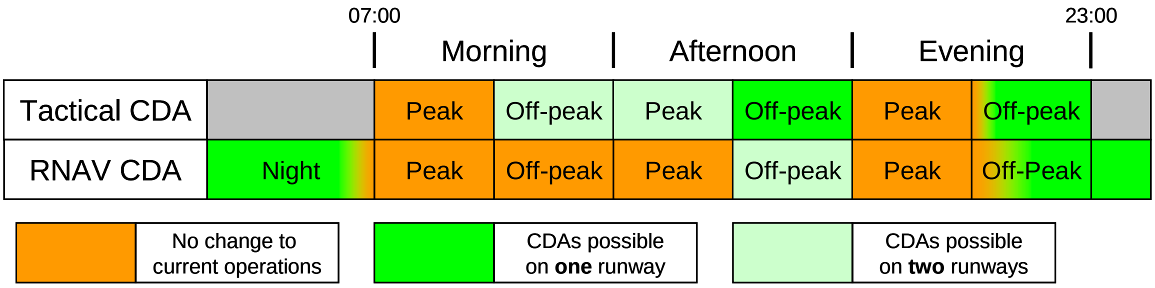
[3] In reference to introduction of new procedures and routes, 'short-term' should be understood as taking several years before significant benefits appear.

Morning and evening arrivals peaks



- Without significant progress in procedures and technology to enable additional capacity in CDA operations, it does not appear to be possible to apply any type of CDAs in the morning or evening arrivals peaks without seriously affecting capacity and introducing significant delays. Without further development, the only option for these periods would be to continue **current operations** as at present.

The following figure summarises these conclusions for the different periods of the day:



It is important to note that the conclusions provided above are based on a high level assessment performed in very short timescales and, although they identify potential options for implementation of CDA before 2020, further study will be required on a number of issues to determine the ultimate feasibility and definitive impacts of such options, as well as the actions required for implementation. Examples of issues that will require further study are:

- Simultaneous use of tactical CDAs on parallel dependent arrivals runways, which would not be possible within current procedures.
- Impact of use of tactical CDAs within the current route structure, in particular interaction with departure routes.
- Validation of assumptions regarding capacity and traffic demand (in terms of traffic growth and how the growth is distributed during the day), in particular for those conclusions that are sensitive to these assumptions.
- Consequences of application of different concepts for physical planning.

Final decisions on an implementation plan (in terms of selected option and timeline) should be made based on a transparent case, describing the effects of these and all other relevant issues.

Finally, extensive EUROCONTROL work on CDAs indicates, that their successful and safe implementation requires effective collaboration and communications between the airport operator, the air navigation service provider and aircraft operators with support from appropriate State authorities. Effective implementation of CDA at Schiphol will require changes to present practice and must therefore be supported by senior management commitment.

Contents

1 Introduction

1.1 This report provides the results of a study aimed at providing a second opinion regarding introduction of continuous descend approaches (CDAs) at Schiphol airport. In past discussions between the relevant stakeholders, two concepts have been proposed for performance of CDAs, but no final decision has been made on the way forward as preferences for one of the concepts vary between stakeholders. This study aims to provide an insight into the feasibility of the two concepts, their impact and any further alternatives that may be considered.

1.2 The second opinion has been developed on request of representatives of the residents living in the Schiphol region. Whilst accepting the importance of the operation of the airport to the region, they would like to ensure that future operations and growth of the airport also take full account of the interests of the residents in terms of quality of living. In particular, minimising nuisance due to noise is very important in this context.

1.3 The study has been performed with the effect of CDA operations on noise nuisance as the starting point, whilst considering all relevant impacts in other areas of the airport operations and stakeholders.

2 Definition of the subject: CDAs at Schiphol

2.1 General

2.1.1 To assess options for CDA operations at Schiphol airport, some background is required: the operational environment in which the CDAs are planned to be operated, the concepts that have been proposed, any planned or expected future developments that may have an impact. This section aims to give a brief overview of the background.

2.2 Operational environment

2.2.1 Runway use

2.2.1.1 There are three main factors affecting operations and runway use at Schiphol airport today:

<u>Infrastructure</u>

2.2.1.2 Schiphol airport has five main runways available for its operations (plus a sixth, shorter runway, runway (RWY) 04/22, currently typically used for general aviation). The geographical layout of these runways is presented in Figure 1.

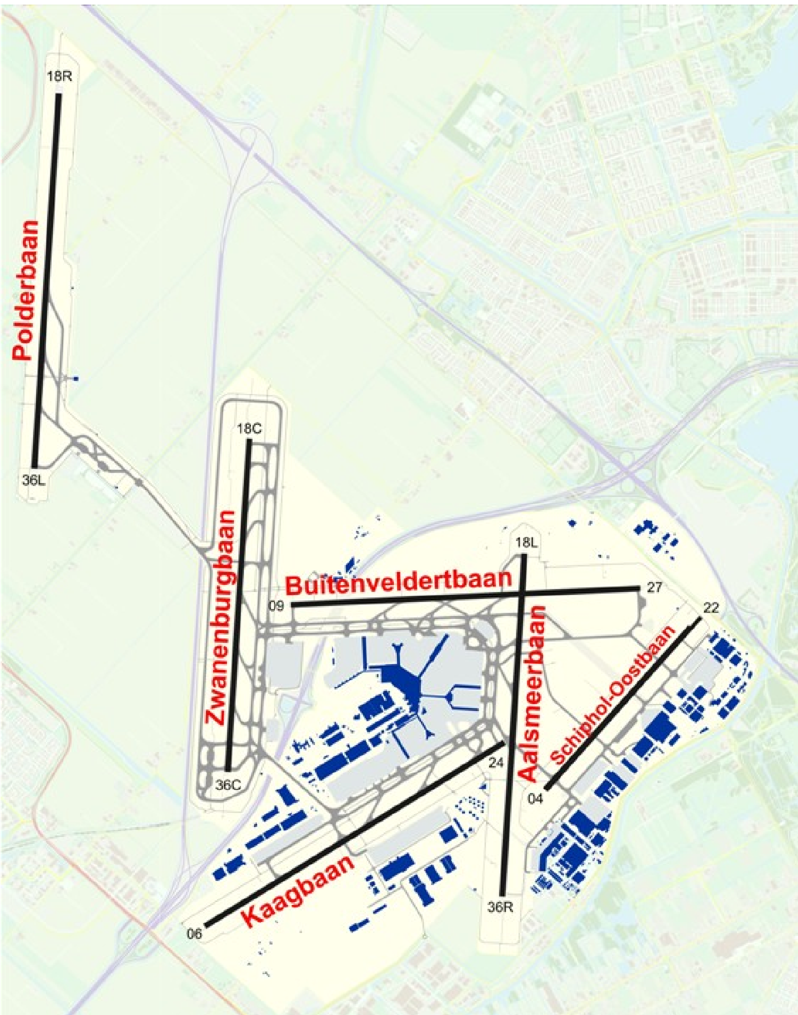


Figure 1 Schiphol runway layout

2.2.1.3 Although the total number of runways is high compared to other airports, there are a number of factors limiting runway use:

- Due to their relative position and orientation, simultaneous operations on combinations of runways can be dependent (limiting the available capacity) or even impossible. Examples are dependent operations on converging landing runways 06 and 36R, and incompatible landing runways 06 and 36C.
- Noise restrictions (which also affect the preferred runway use, as will be discussed below) prohibit or severely limit use of runways in certain directions. The most obvious example of this is RWY 18R/36L, which can not be used for arrivals from and departures towards the south. Other examples are RWY 06/24 (very limited use from/towards the northeast) and RWY 18L/36R (not used from/towards the north).[4]

Traffic distribution over the day

2.2.1.4 Daily operations at Schiphol airport take place using a concept of alternating peak periods - periods in which either arriving or departing traffic is predominant. This concept is essential to the business model of the main carrier operating at the airport, KLM. Schiphol is KLM's main hub airport, with approximately 70% of KLM passengers travelling through Schiphol airport being transfer passengers, i.e. passengers who transfer from one flight to a next flight with Schiphol as an intermediate stop in the overall journey. This explains why a model of inbound peaks, transfer and outbound peaks is so critical: to efficiently and successfully operate in this way, high connectivity (i.e. many inbound flights 'connecting' to many outbound flights to maximise the number of destinations and frequencies that can be offered to a wide market) and high reliability of capacity (to ensure transfer of passengers from arriving to departing flights is not disrupted by delays, leading to missed connections) are required.

2.2.1.5 Applying the alternating peak concept to runway use means that the airport alternates between periods of requirement for higher arrivals capacity or higher departures capacity. During these periods, a so-called '2+1' runway use concept is applied: during arrivals peaks two dedicated arrivals runways and one dedicated departures runway are in use, during departures peaks this situation is reversed. During transitions between peaks, a limited period of '2+1+1' runway use is acceptable, where the additional runway can be used to process part of the remaining traffic flow of the previous peak, until that traffic flow can be handled by a single runway only.

2.2.1.6 At the moment, a total of 11 peaks occur during the day between (approximately) 0700 and 2130 local time - 6 departures peaks and 5 arrivals peaks. The distribution of traffic over the day is illustrated in Figure 2.

[4] http://www.luchtverkeersleiding.nl/frameset.php?source=uitleg_baangebruik

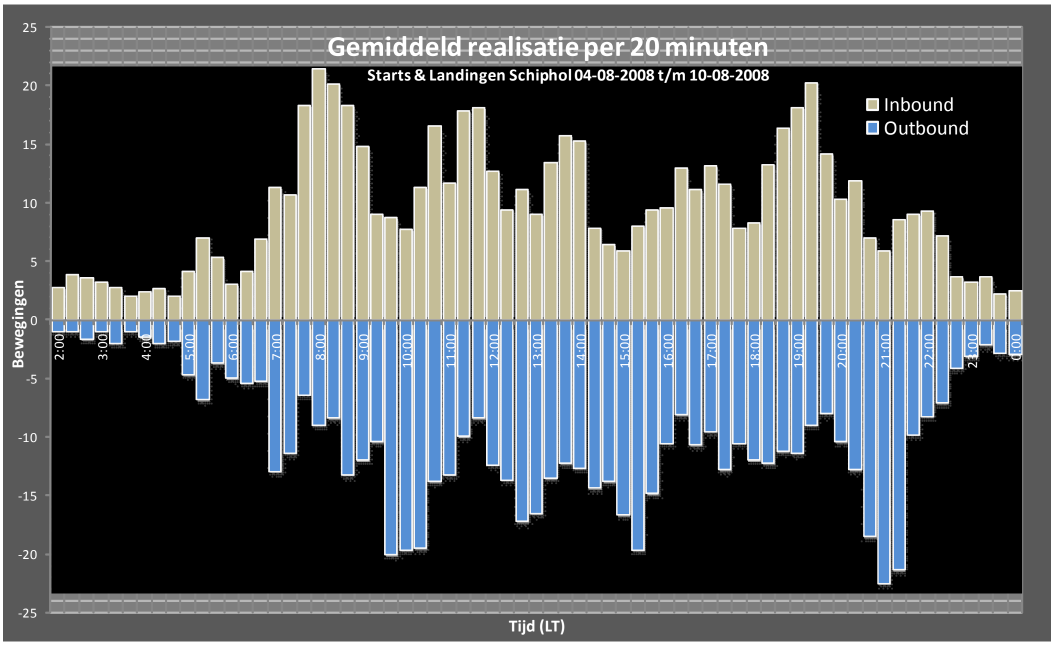


Figure 2 **Average traffic distribution during a day at Schiphol airport**

2.2.1.7 The frequent number of runway changes as a result of the alternating peak concept, in combination with the complex infrastructure and limited size of the available airspace, leads to high complexity of operations.

Noise regulations

2.2.1.8 Schiphol airport is operating within strict noise regulations. These regulations have been defined through the use of so-called ‘handhavingspunten’ - points around the airport for which a maximum annual noise quota is defined. The location and quotas of these points have been defined in such a way that more noise can be allowed in areas with low density of population and less noise allowed in densely populated areas. Two sets of points exist: one for operations during the whole, 24-hour day, and one for night hours only (23:00-06:00 local time).

2.2.1.9 A preferential runway system is in place which is related to these points and quotas, with highest preference put towards operations on runways that lead to noise nuisance in the less densely populated areas mentioned above. In practice this leads to preferred use of arrivals runways 06 (‘Kaagbaan’) and 18R (‘Polderbaan’), as they have the most ‘space’. However, the order of preference is re-evaluated on a weekly basis to ensure all points stay within the quotas for the operational year (1 November - 31 October).

Figure 3 Location of 'handhavingspunten' around Schiphol airport

2.2.1.10 An example of the order of runway combinations for an arrivals peak period (two arrivals runways, one departures runway) according to the noise preferential runway use system is provided in Table 1. Similar orders of preference for possible runway combinations exist for departures peaks, off-peak periods and night time. The high preference for runways 06 and 18R can easily be recognised from this overview. Typically, combinations with preference 1, 2 or 3 account for close to 90% of arrivals peak times during the year.

Order of preference	Main arrivals RWY	Secondary arrivals RWY	Departures RWY
1	06	36R	36L
2	18R	18C	24
3	18R	18C	18L
4	36R	36C	36L
5	27	18R	24
6	18R	22	24
7	18R	22	18L
8	06	09	09

Table 1 **Example: arrivals peak runway preference order, inside UDP**[5]

2.2.1.11 In graphical form, these combinations can be represented as follows:

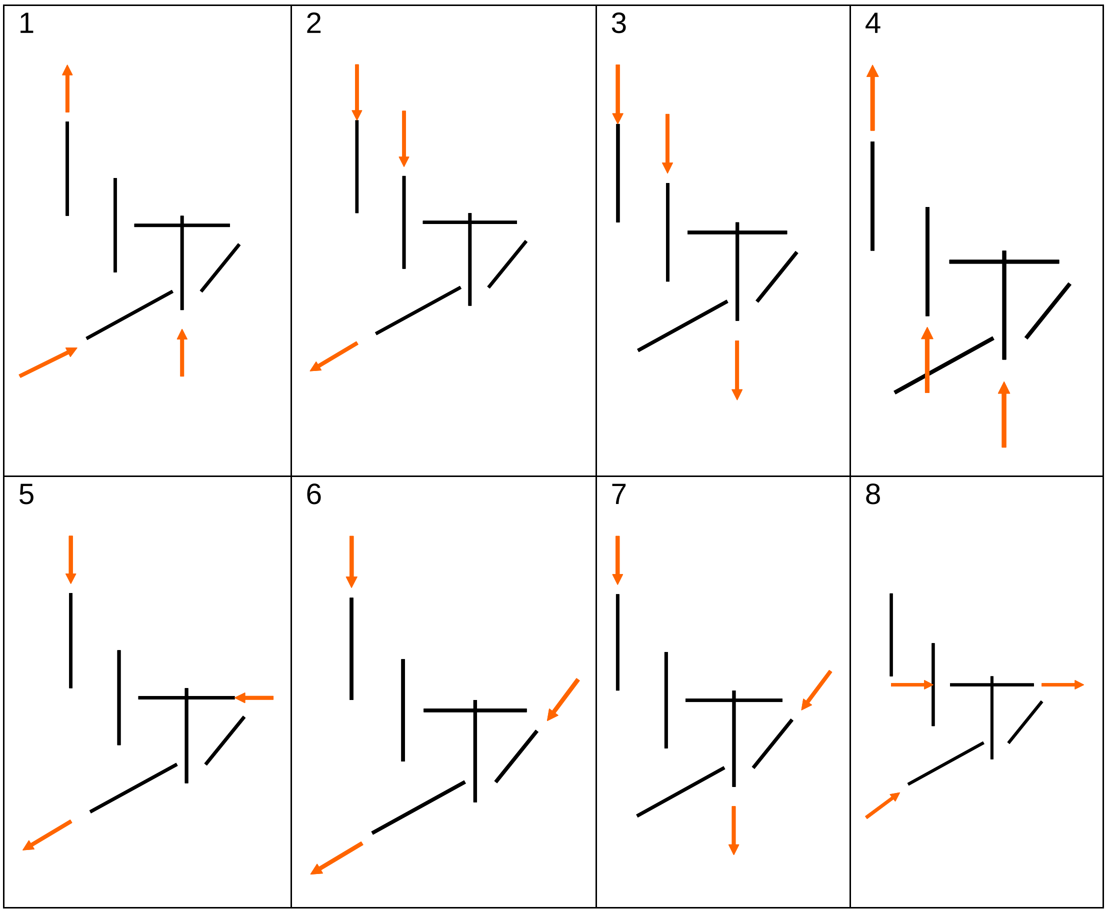


Figure 4 **Graphical representation of noise preferential runway system example**

[5] http://www.luchtverkeersleiding.nl/

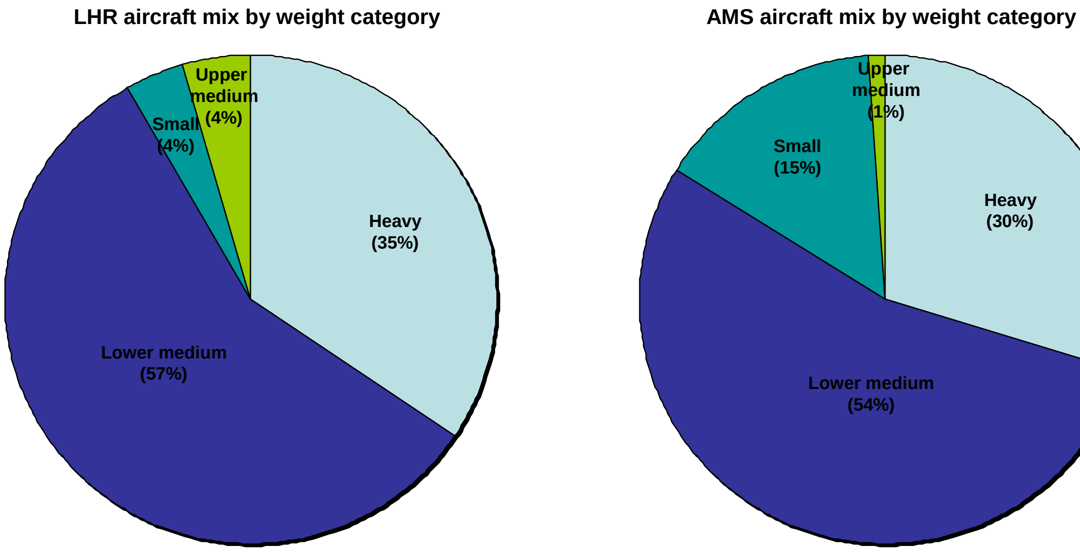
2.2.1.12 Runway use during the day is determined based on the three factors discussed above, infrastructure, traffic distribution and noise regulations, in combination with weather conditions (in particular wind conditions) and runway availability.

2.2.2 Runway capacity

2.2.2.1 In addition to runway use, runway capacity is an important characteristic in the current assessment. Two important aspects affecting the runway capacity are mentioned here.

- **Traffic mix** Current declared hourly arrivals runway capacity at Schiphol is 37 arrivals per hour for a single runway. A very important factor limiting the available runway capacity is the traffic mix, i.e. the mix of different types of aircraft operating at the airport. The very wide range of aircraft types in operation at the airport is a typical characteristic of Schiphol, and influences the runway capacity: a sequence of aircraft of different type and performance will require larger average separations than a sequence of similar aircraft as a result of wake vortex separation minima and speed differences.

  To illustrate this point, the following figure shows the traffic mix of Schiphol and of London Heathrow, where the peak arrivals runway capacity using its single arrivals runway is 44 arrivals per hour (not sustainable) and average arrivals runway capacity is around 41 or 42 arrivals per hour.



Source: Air Transport Intelligence

Figure 5 Comparison of traffic mix at Heathrow and Schiphol[6]

It is expected that the mix of aircraft sizes at Schiphol will remain fairly constant over time as it is driven primarily by KLM's business model which requires

[6] The figure uses weight categories as applied in the UK to highlight the proportion of aircraft of category 'small'. It should be noted that a different way of categorisation is used at Schiphol from the one presented here.

small aircraft operating on ‘thin’ routes to feed large aircraft operating on ‘thick’ trunk routes in the hub and spoke model. Although the performance of small aircraft is likely to improve in the future this will be offset by aircraft separation on approach driven by wake vortex considerations. This might actually get worse as super-heavy aircraft, such as the A380 enter the traffic mix.

- **Runway dependencies** The dependencies that can exist when operating two arrivals runways simultaneously were already referred to earlier when discussing the runway infrastructure. For the available capacity it is important to note that, as a result of these dependencies, peak arrivals capacity when operating two runways is 68 arrivals per hour, which is less than the 74 that might be expected based on capacity of a single runway of 37 arrivals per hour or the 80 that might be expected to be achievable for very short periods when the conditions and traffic mix are favourable.

2.2.3 Terminal Manoeuvring Area

2.2.3.1 The Amsterdam TMA - like Dutch airspace as a whole - is of limited dimensions (flight time from FIR boundary to TMA boundary is only in the order of 10 minutes) and covers some very complex routes: currently, for arrivals, there are three Initial Approach Fixes (IAF) at the TMA boundary, SUGOL in the west, ARTIP in the east and RIVER in the southwest, and arrival routes exist from all three IAFs to all relevant runway ends.

2.2.3.2 The figure below shows tracks for all flights for a period of a number of hours. Arriving aircraft are highlighted in red and departures in blue. During the period covered by the figure, RWY 18R was used as primary arrivals runway, with RWY 18C as secondary arrivals runway. Departures runways were 24 and 18L.

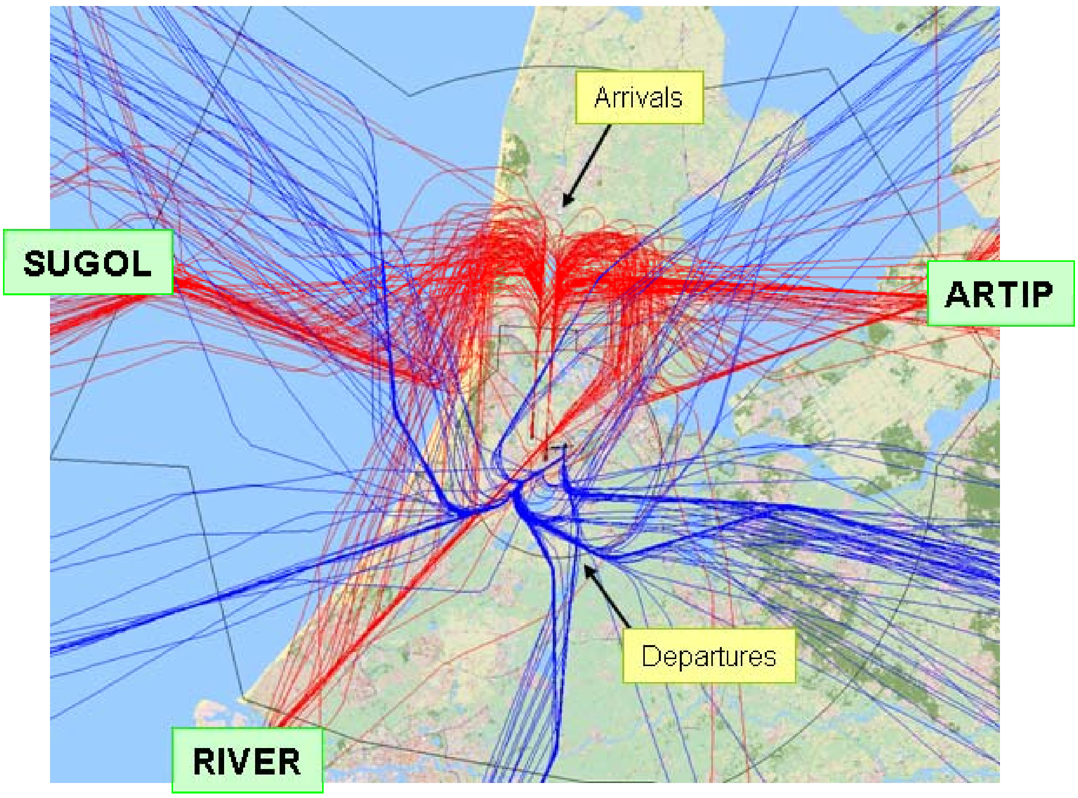


Figure 6 **Actual radar tracks of arrivals and departures**

2.2.3.3 The figure clearly shows two important characteristics:

- the vectoring of aircraft (and hence dispersions of noise) that is currently taking place to ensure efficient operations. It can also be seen that there is some flexibility in this vectoring: most arrivals coming through the RIVER IAF (to the southwest of the map) are vectored via the west side of the airport and merged with traffic coming through the SUGOL IAF (to the west of the map), whereas some flights from RIVER are vectored via the east side of the airport.
- the complex network of arrival and departure routes and the often acute angles at which these cross, leading to a requirement for clear vertical separation.

2.2.3.4 The option to use holding stacks at the IAFs is available, but this procedure is currently avoided as much as possible.

2.2.3.5 The complexity of operations in the TMA is further increased by flights to and from the airports of Rotterdam and Lelystad.

2.2.4 Future developments

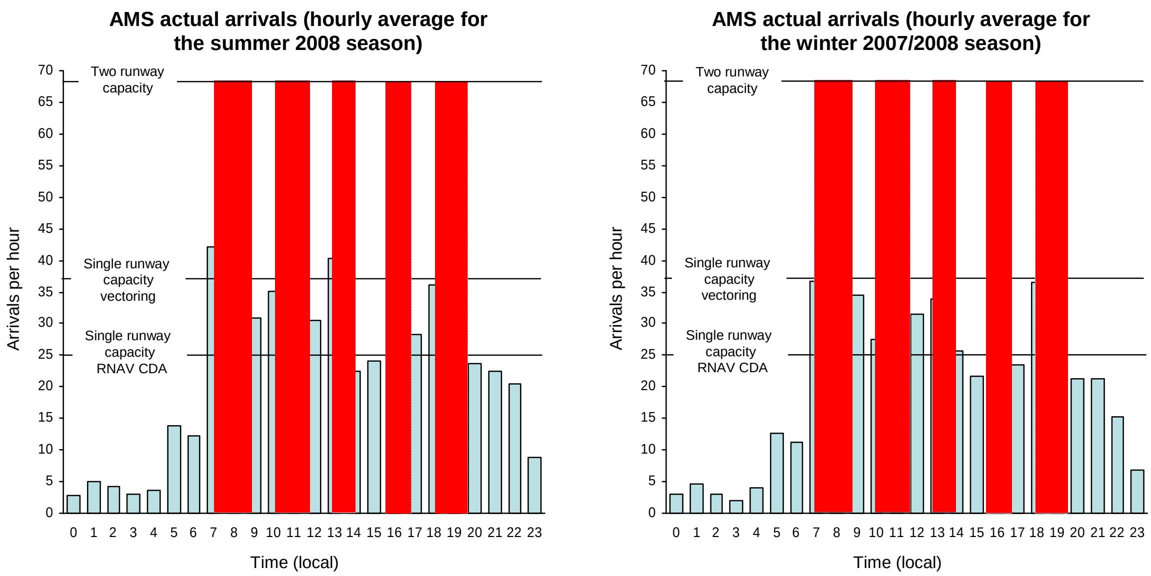
2.2.4.1 This report does not intend to give a full overview of expected future developments at Schiphol airport. However, a number of issues need to be taken into account:

- The basic principle of the alternating arrivals and departures peak concept that is in operation today can be expected to remain in use in the future. Characteristics such as start and end times of peaks may change, but this will not significantly affect the outcome of the current study.
- Similarly, the current traffic mix at Schiphol, covering a wide range of aircraft types (with equally wide ranging performance characteristics) can be expected to remain in operation for the foreseeable future – use of small aircraft on feeder routes is critical to KLM's hub and spoke operation.
- Discussions on the allowable growth of the annual number of movements at the airport up to and including the year 2020 are underway and are expected to come to a conclusion in the near future.
- In terms of hourly capacity, KLM has expressed a desire for a peak hour capacity of 80/40 to become available, i.e. 80 arrivals and 40 departures in an arrivals peak, and vice versa in a departures peak. Demand at this level cannot be met in a sustainable way with current operations and the current traffic mix. Depending on the outcome of discussions on allowable future growth of annual movements as mentioned in the previous bullet, the 80/40 capacity may not be required up to 2020, but should still be considered a long term goal.
- It is understood that use of a second arrivals runway during departures peak periods has been agreed between different stakeholders, to increase the robustness and resilience of operations. Within the agreement, such a second arrivals runway can be made available for a maximum of 3 hours per day and handle about 40 to 50 arrivals in that period.

2.2.4.2 For the moment, focus on future developments is limited to the period up to 2020. After 2020, the effects of ongoing international initiatives such as the Single European Sky ATM Research (SESAR) programme and American Next Generation Air Transportation System (NextGen) are expected to become noticeable. A number of national and international developments that may already deliver improvements before 2020, in particular in relation to CDAs, is described in Annex A.

2.2.4.3 A final point for consideration is future traffic growth. The operational concept to be employed to implement CDAs clearly has a significant dependence on the traffic demand and on the capacity that can be delivered by the concept. Figure 7 shows the **actual hourly arrivals patterns** averaged for each hour for Schiphol for the current summer (2008) season and the last full winter season, 2007/2008. These charts are derived from Central Flow Management Unit (CFMU) data and show the actual evolution of traffic throughout the day. They do not, however, show the day-to-day and hour-to-hour bunching of traffic that will occur within each hour and should, therefore, be used only for strategic assessment rather than precise operational planning. Note, also, that the traffic patterns shown in this figure are necessarily different to those most often used in discussions on this topic as the latter is based on schedules.

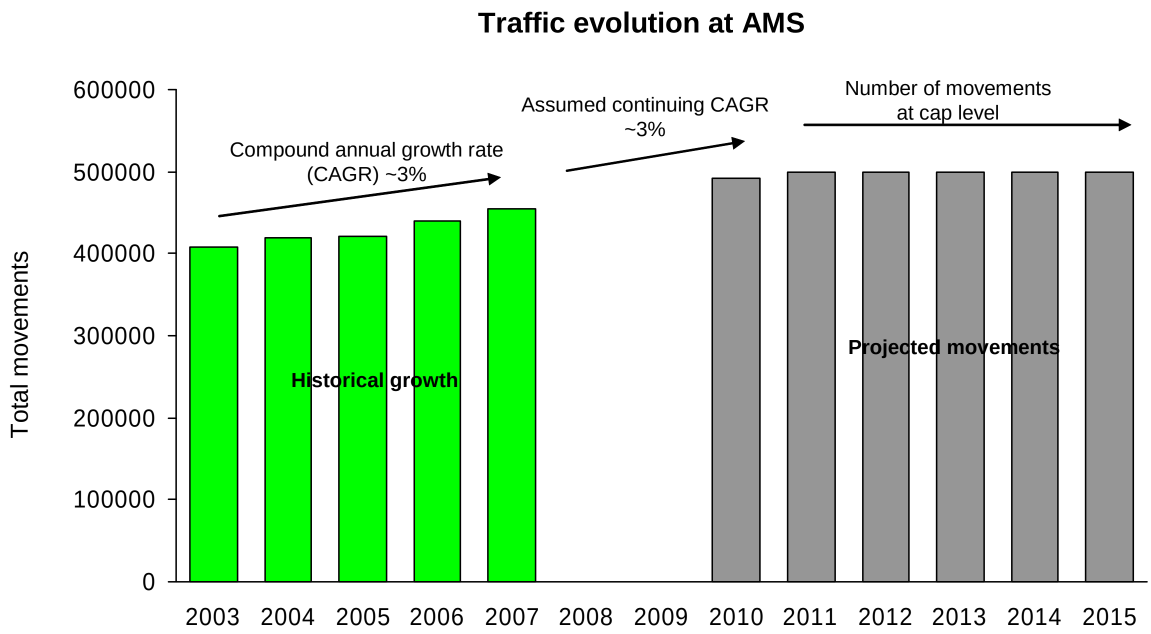
2.2.4.4 The figure also indicates the single runway capacity in current operations (around 37 arrivals per hour) as well as the projected capacity for RNAV CDAs (see Section 2.3.4 for more detail). The red bars on the chart show the current peak periods when it is necessary to operate two arrivals runways for purely capacity reasons. The red bars are not completely aligned to the traffic peaks because of the limited granularity of the averaging process.



Source: Eurocontrol Central Flow Management Unit
Note: Arrivals peaks when 2 runways are operated are shown shaded

Figure 7 Actual hourly arrivals demand at Schiphol for the current summer season and the previous winter season

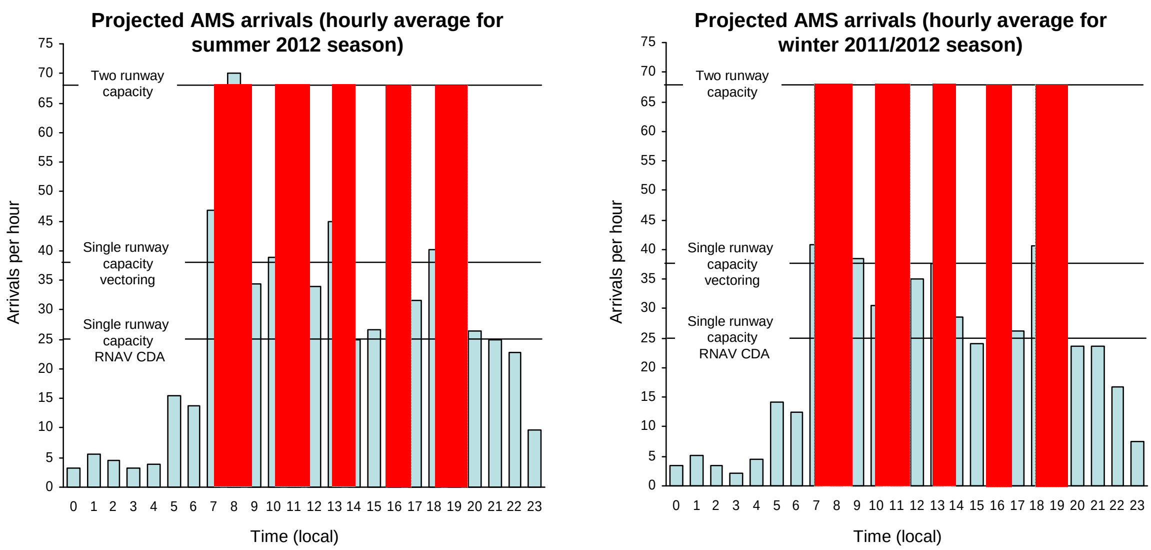
2.2.4.5 Although Figure 7 gives a snapshot of the current situation, it is clearly important to understand how traffic might grow in the future. Figure 8 shows the historical growth in aircraft movements at Schiphol over the past five years. This shows a compound annual growth rate of just under 3%. Projecting this forwards, indicates that the traffic will reach the capacity cap (currently under discussion; for this second opinion the cap was assumed to be 500000 movements per year, if the final figure is significantly different then the effect on the conclusions may need to be considered) during 2010 or 2011.



Source: Air Transport Intelligence, Helios analysis

Figure 8 Historical and projected growth of aircraft movements at Schiphol

2.2.4.6 Figure 9 shows the results of applying the 3% growth rate to the current arrivals profiles and assuming the ratio of peak to off-peak traffic is maintained.



Source: Eurocontrol Central Flow Management Unit, Helios analysis
Note: Arrivals peaks when 2 runways are operated are shown shaded

Figure 9 Projected arrivals demand for Schiphol for the summer season 2012 and winter season 2011/2012

2.2.4.7 The points to note when comparing the peak traffic in Figure 7 and Figure 9 are:

- use of the second arrivals runway between the morning arrivals peaks absorbs the additional traffic and will provide additional reliability through a capacity buffer/fire break
- the traffic in the afternoon outside the arrivals peak periods has grown to approach or exceed the capacity that would be available from a single runway RNAV CDA operation (see Section 4.4.2 below) although the traffic could comfortably be handled on a single runway with conventional operations

2.3 CDA concepts

2.3.1 General

2.3.1.1 EUROCONTROL, in its CDA guidance material[7] provides a general definition for a CDA. It is important to understand this definition because, although specific CDAs are naturally tailored to local situations and no one-size fits all, it is emerging as not only the European standard but is expected to be recognised at the global level through the International Civil Aviation Organisation (ICAO). The EUROCONTROL definition is:

> "*Continuous descent approach is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions.*"

2.3.1.2 This definition gives maximum scope for adaptation to local circumstance, is not prescriptive and has been taken as the basis for the subsequent analysis allowing, as it does, different potential solutions.

2.3.2 Amsterdam specific situation

2.3.2.1 In the specific Schiphol context, LVNL defines a CDA as "*a P-RNAV supporting noise reduction approach where both the vertical and lateral path has been defined as a fixed route. The vertical path is continuous (without horizontal flight)*"[8]. This is a much more prescriptive and less flexible definition of a CDA than that promulgated by EUROCONTROL

2.3.2.2 Currently, CDAs are used during the night hours (2300-0600). The procedures used during this period have been specifically designed for the night time operations. The intention is to develop new RNAV CDA routes and procedures which can be used outside the night hours. With such routes and procedures it will become possible to expand the use of CDAs (outside arrivals peaks), possibly using a stepwise approach in which initially the expansion would only cover a limited number of hours during the day and then eventually during the whole day outside arrivals peaks. No definitive timeline has been defined for this process - CDAs during the whole day are expected to be in place by 2020, but sooner would be preferred if possible.

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[7] 'Continuous Descent Approach Implementation Guidance Material', EUROCONTROL, May 2008, www.EUROCONTROL.int/environment/gallery/content/public/documents/cda_brochureA4_may08_web.pdf

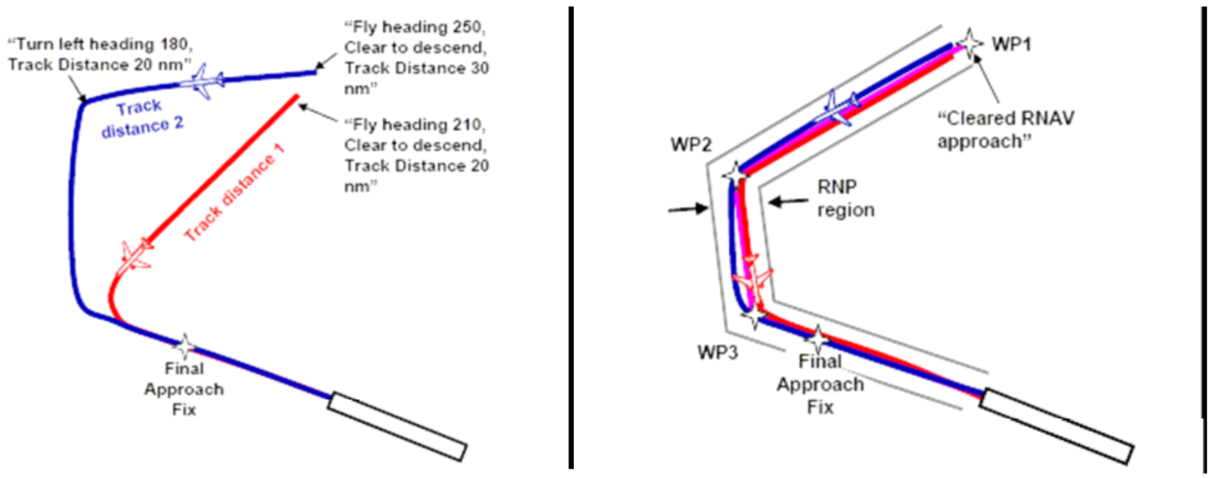
[8] Request for proposal for the current project, 'Continuous Descent Approaches (CDA) Schiphol - Assignment second opinion', 26 June 2008

2.3.2.3 Two concepts have been proposed for expanding the use of CDAs during the day. The main difference between the concepts that is of importance here is the runway use. Before describing the two concepts, it is important to discuss the two main techniques that may be used to operate CDAs, as they are closely related to the concepts.

2.3.3 CDA techniques

2.3.3.1 The main difference between the two CDA techniques that are currently in operational use at different airports around the world lies in the definition of the lateral path.

2.3.3.2 In a tactical CDA, the lateral path of the aircraft is defined through instructions provided to the flight crew by the air traffic controller. In an advanced CDA, the lateral path is pre-defined through a standard arrival route (STAR).



Tactical CDA using vectoring

Advanced CDA using standard route

Figure 10 Basic principles of different CDA techniques

2.3.3.3 Both techniques have advantages and disadvantages (noting that these are not necessarily specific to CDAs).

2.3.3.4 In terms of throughput, using a standard route will have a negative impact. To guarantee required separation on the runway, a buffer needs to be created between aircraft with different performance (different speeds) flying the same, standard route. This disadvantage does not exist in a standard CDA, when different aircraft can be kept on different paths for a longer period, removing the need for a buffer.

2.3.3.5 At the same time, a tactical CDA can have an impact on the workload for both controller (who has to provide relevant instructions to all flights and coordinate both lateral and vertical separation) and pilot (who has to implement instructions and possibly adjust flight settings as the rate of descent may depend on the remaining flight distance and therefore rate of descent may need to be changed as flight distances change after controller instructions) at various stages of the approach. However, EUROCONTROL work has indicated that CDA may result in lower pilot and controller workload in some areas, such as RTF communications, and that in operational trials neither controllers nor pilots have reported any major difficulties in terms of workload[9].

2.3.3.6 A final difference mentioned here and of which opinions on advantage or disadvantage differ, is the ground area affected by aircraft noise during the CDA. In a tactical CDA, aircraft tracks vary between flights and the related noise is spread out over a wide area. When using a standard route, the noise is concentrated in a limited area where noise levels can be quite high.

2.3.3.7 A combination of use of RNAV and tactical CDAs is possible (although not simultaneously; in such a combined situation RNAV CDAs could be applied in periods of low traffic density and tactical CDAs when traffic levels increase). This does however lead to a requirement for significant development effort as focus is divided between the two concepts.

2.3.4 Proposed concepts for Schiphol airport

2.3.4.1 As mentioned, two concepts for the application of CDAs have been proposed for Schiphol airport.

2.3.4.2 In the first concept, the main objective is to follow the noise preferential runway system and in particular the '2+1' runway use concept during CDA operations. It has been assumed that in this case use of tactical CDA procedures will be necessary as a procedure with fixed routes is expected to be unable to provide sufficient capacity on a single runway. <u>This concept is preferred by the residents.</u>

2.3.4.3 In the second concept, the main characteristic is the use of fixed P-RNAV routes. As the use of fixed routes together with CDAs limits the runway capacity that can be achieved, two arrivals runways are expected to be required at all times (outside night hours) to accommodate CDAs. Runway allocation for individual flights will then take place more or less dependent on TMA entry point: one runway to be used for flights coming in from the west, the other runway used for flights coming in from the east, and flights coming in from the south split between the two runways. <u>This concept is preferred by LVNL.</u> Use of fixed routes and RNAV in general (i.e. not necessarily within the scope of CDAs) is part of the long term strategy of LVNL and in line with international developments.

2.3.4.4 One of the main factors to be considered in assessing the two concepts is the capacity that can be achieved. Based on current operations and the restrictive definition of CDAs as applied by LVNL, a maximum runway capacity of 25 arrivals per hour is used when RNAV CDAs are in progress, although this figure is expected to grow slightly over time as experience with RNAV CDA operations grows.

[9] 'Attitude to change in ATM operations - Introduction of CDA trials in Manchester, Bucharest & Stockholm', EEC Note No. 08/07, EUROCONTROL Experimental Centre, November 2007

3 Problem definition

3.1 General

3.1.1 It is considered critical that all stakeholders have a common understanding of the purpose of the current study. For this reason, the main question being looked in to is repeated here. As background to the question, a brief introduction to the stakeholders and their objectives is also given.

3.1.2 The definition of a second opinion was requested by representatives of the local residents and therefore their interests have been taken as a starting point.

3.2 Identification of stakeholders and their objectives

3.2.1 The following stakeholders have been considered in relation to operations at Schiphol, and in particular regarding implementation of CDA techniques:

- Local residents
- Air navigation services provider: Luchtverkeersleiding Nederland (LVNL)
- Main carrier: KLM
- Airport operator: Amsterdam Airport Schiphol (AAS)
- Regional government: Bestuurlijke Regie Schiphol (BRS) represented by Province of Noord-Holland

3.2.2 These stakeholders have different interests in and objectives regarding implementation of CDA procedures:

- For the local residents, the basic objective is simple: to minimise the impact the operation at Schiphol airport has on their daily lives. As they acknowledge that the operation of 'Mainport Schiphol' has clear benefits to the region, the residents do not oppose the airport as such, but within agreed operational characteristics, the nuisance should be as low as possible. In particular for the introduction of CDAs, the aim is to reduce noise nuisance.
- The main purpose of the provision of air navigation services by LVNL is to ensure the safe and expeditious movement of traffic. Within the concept of applying CDAs, LVNL will prefer a concept with high safety levels whilst meeting the requirements of its primary customers, the aircraft operators. This means LVNL will aim for limiting workload and complexity of the operation while providing sufficient capacity and reliability. The air navigation service provider is also fully aware of the interests of the residents and will try to combine meeting customer requirements with minimising nuisance for residents.
- For the main carrier of the airport, KLM, the main focus for airport operations is to enable the business model it chooses to operate; in the case of KLM this is the hub and spoke operation with alternating inbound and outbound peak periods, as described earlier. To enable these operations in the future, KLM has expressed a desire for a declared hourly peak capacity in the long term of 80/40, i.e. 80 arrivals and 40 departures in an arrivals peak period. If operation of CDAs can be combined with the provision of sufficient capacity, this can have benefits to KLM, e.g. in terms of reduced fuel burn.

- For the airport operator, it is important that good service is provided to the airlines and that the airport is able to operate and grow within the conditions of its license. Regarding provision of good service in relation to CDAs, the airport is largely dependent on the ability of LVNL to meet the requirements of the aircraft operators. For the operation and growth of the airport, the applicable noise regulation and the general acceptance by its 'neighbours', the residents, are very important. The introduction of CDAs reduces the nuisance due to noise for people living around the airport.
- For the regional and local governments it is important that on the one hand the future of Schiphol airport with a wide range of international destinations, an important economic factor, is guaranteed, while at the same time nuisance to the residents on a day-to-day basis is minimised and flying patterns are stable along fixed routes with marginal deviation. This latter objective is of importance in terms of physical planning, as it allows for clear identification of a limited area in which noise will be concentrated, with surrounding areas being available for development.

3.3 Question for the second opinion

3.3.1 The request for the current project described the question to be considered as the need to provide "*expert judgement on the validity of:*

- *The following conclusions by LVNL within the optimised Sustainable Mainport concept:*
  - *In order to be able to develop new arrival routes and to gain sufficient experience to finally introduce high density CDAs in combination with fixed arrival routes in the TMA, space for development needs to become available by the use of a second landing runway in landing peaks.*
  - *The availability of a second runway makes it possible to consequently as from 2012 increase the realisation of noise abatement approaches in combination with fixed arrival routes in the TMA until 2020.*
- *The statement by residents that - independent from the question when the European ATM system (SESAR) will be deployed in the Netherlands and with continuation of the peak capacity of 36 flights - higher altitude approaches, CDAs and fixed arrival routes at daytime with an optimal noise preferential runway use (see chapter 4 item 2 for specifications):*
  - *Can be introduced completely before 2020 by using the significant number of low traffic periods.*
  - *Can start significantly earlier with the use of holding stacks and/or variable baselegs (trombones) for balancing traffic flow and capacity.*

3.3.2 *The solution must fit in internationally accepted safety targets.*" [10]

3.3.3 During the initial phases of the project and following the EUROCONTROL definition it became clear that alternatives to the LVNL proposal should be considered on a wider scale than mentioned in the original request, including a mixed environment where conventional operations, tactical CDA and RNAV CDA

[10] Request for proposal for the current project, 'Continuous Descent Approaches (CDA) Schiphol - Assignment second opinion', 26 June 2008

could be applied as the noise and traffic (capacity) requirements changed throughout the day.

4 Assessment

4.1 General

4.1.1 As indicated in the introduction, the second opinion was requested by the residents, with their main focus and interest being in minimising the nuisance on the ground due to aircraft noise.

4.1.2 This section will assess the two concepts, their impact in terms of noise nuisance, and any relevant trade-offs between reduction of noise and impact in other areas.

4.2 Criteria

4.2.1 In addition to noise, a number of criteria play a role in assessing the two concepts. An overview of these criteria and how they have been used is provided below.

4.2.2 Criteria such as punctuality and connectivity, which can be very important to the airlines, are not considered directly in relation to CDAs as they are closely linked to capacity and reliability: if capacity and reliability are sufficiently high, punctuality and connectivity should follow.

4.2.3 In the assessment, noise and capacity have been analysed in some detail, with only a high level analysis being provided for the other criteria.

Criterion	Relation to assessment
Safety	Safety is considered a **prerequisite**. Although this means that no concessions shall be made to safety levels, safety can be an important criterion as different concepts can have different safety impact (and therefore may require different effort to guarantee safety).
Environmental impact	
Noise	Noise is used as the **primary evaluation criterion**: the objective is to minimise nuisance due to noise. However, nuisance is nearly impossible to quantify and even a qualitative assessment is difficult as opinions on what constitutes 'nuisance' differ.
Emissions	Emissions are a **secondary evaluation criteria**: the objective will be to minimise emissions, but to achieve this a number of trade-offs can be made. These trade-offs will be indicated clearly, but a decision can not be made within this study; a policy decision on the way forward is required on this.
Capacity	
Airport	For the airport capacity, providing sufficient capacity to meet traffic demand is taken as a **requirement**. For each option it will be assessed what needs to be done to achieve the 80/40 capacity and, if applicable, reasons for not achieving the required capacity will be given.
Runway	Runway capacity is likely to be a direct consequence of the applied concept, and considered here as a means to achieve the required airport capacity.
Reliability	Like airport capacity, reliability (of availability of the required capacity) is considered a **requirement**.
Predictability	Predictability (of arrival times) is a **secondary evaluation criterion**. Poor predictability will have negative consequences for airline operations.
Economic	
Micro-level	Economic impact at micro-level is a **secondary evaluation criterion**: this impact covers e.g. fuel costs for the airlines. As with emissions, the aim will be to minimise these costs, but trade-offs with other areas exist.
Macro-level	At macro-level, the economic impact is also a **secondary evaluation criterion**, as regional development may depend on the airport operations, both in terms of noise load (and its impact on physical planning) and in terms of benefits of airport growth.

Table 2 Overview of evaluation criteria

4.3 Trade-offs

4.3.1 A number of trade-offs exist between the different criteria as defined in the previous sub-section, in relation to the different CDA concepts. The most important trade-offs are discussed here. A number of the trade-offs have already been mentioned in previous sections of this report and will be repeated here briefly.

Lateral path definition vs runway capacity

4.3.2 This issue was already mentioned in Section 2.3.3. There is a trade-off between the runway capacity that can be achieved and the routing procedure that is applied. RNAV CDAs are typically used in airports with limited traffic density or in low traffic periods on busier airports, as they limit the runway capacity that can be achieved. Higher capacity may become possible in the future as experience grows and with the help of ATCO support tools. With the application of vectoring, much higher capacity can already be achieved today.

Lateral path definition vs ground area affected by noise

4.3.3 The second trade-off to be discussed was also mentioned in Section 2.3.3 and concerns routing procedures and area affected by aircraft noise. When using fixed routes, all aircraft will obviously follow a lateral path that is very similar, and the area at ground level that is affected by noise is small, but the noise levels within this area are high. Alternatively, using vectoring, aircraft routes, and consequently affected area at ground level, are much more dispersed.

Capacity enhancing measures vs flight efficiency

4.3.4 Measures such as stacks and trombones can help to achieve higher capacity during CDA procedures, but they also come at a cost: increased flying time leads to increased fuel burn, which is a direct cost to the aircraft operator paying for the fuel and an indirect cost in terms of increased emissions impacting on climate change[11].

Capacity enhancing measures vs predictability and punctuality

4.3.5 Similar to the previous point, stacks and trombones will reduce predictability as it is not always clear at an early stage how much time will be taken up in the holding stack or the extended legs of the trombones. In particular use of holding in the stacks as a measure to keep up capacity can lead to significant delays. Issues with predictability can occur both at the tactical and strategic stage.

Capacity and reliability vs predictability and punctuality

4.3.6 This point was already referred to in Section 4.2. To successfully operate its hub operations, it is very important to KLM that predictability and punctuality at Schiphol are high, because this maximises the number of passengers successfully transferring from an arriving to a departing flight. Passengers missing connections (‘non-performance’) can lead to high costs for KLM. High punctuality means a large number of flights arriving on or close to their scheduled arrival time, allowing for sufficient time to make the transfer from one flight to the next. High predictability means that any issues and disruptions that may affect transfers can be dealt with more easily as details are known further in advance.

4.4 Impact of the two concepts and potential alternatives

4.4.1 Noise

4.4.1.1 As mentioned, the primary evaluation criterion is noise. In the concept preferred by the residents, noise will continue to be dispersed over a wider area during CDA operations and as a result the number of people affected by noise remains the

[11] Impacts on local air quality are restricted to altitudes lower than 300m

same as in current operations in the same period of the day. For those people in the outer region (i.e. the region affected by the approach before the final approach fix) that experience noise the situation will get slightly better as a result of CDA operations (leading to reduction in noise volume).

4.4.1.2 In the LVNL preferred concept, noise will be concentrated in a limited area during CDA operations, but use of a second runway will be required. The benefits for people affected by noise from arrivals on the primary runway is clear, and in most cases benefits are even more significant than in the residents preferred concept. However, use of a secondary arrivals runway outside arrivals peak periods means a group of people will be affected by noise that has not previously experienced any noise during these periods.

4.4.1.3 This is illustrated in Figure 11. A number of distinct areas can be identified in these figures:

- Area affected by final approach path. In this area, aircraft should have established a stable approach on ILS, independent of the method for lateral path definition used in the earlier phases on the approach. As a result, for this study the only relevant aspect affecting noise in this area is the **number of movements on the relevant runway**.

- Area affected by initial approach path. In this area, three aspects are important to consider as they will affect changes in noise. The first is the same as for the final approach path: the **number of movements on the relevant runway**. The second aspects is also obvious: the **operation of CDAs**. The third aspect is related to the crucial issue of lateral path definition in CDA operations: using **fixed routes or vectoring**. To assess this third aspect, the area affected by the initial approach path needs to be split further into two parts:

    - Area affected if lateral path is defined as a fixed route.

    - Additional area affected if lateral path is defined through vectoring.

4.4.1.4 In terms of noise nuisance, as indicated in Table 2, even a qualitative assessment of the effects is difficult. The impact of the concept preferred by LVNL can be quite high for people living near the secondary runway and is in direct contradiction to the resident's desire to limit noise, as in this concept they would be exposed to noise whereas currently they do not experience any noise outside arrivals peaks. At the same time, the number of movements on the primary runway will be reduced when a secondary runway is put into use, providing some benefits to those people affected by the primary runway.

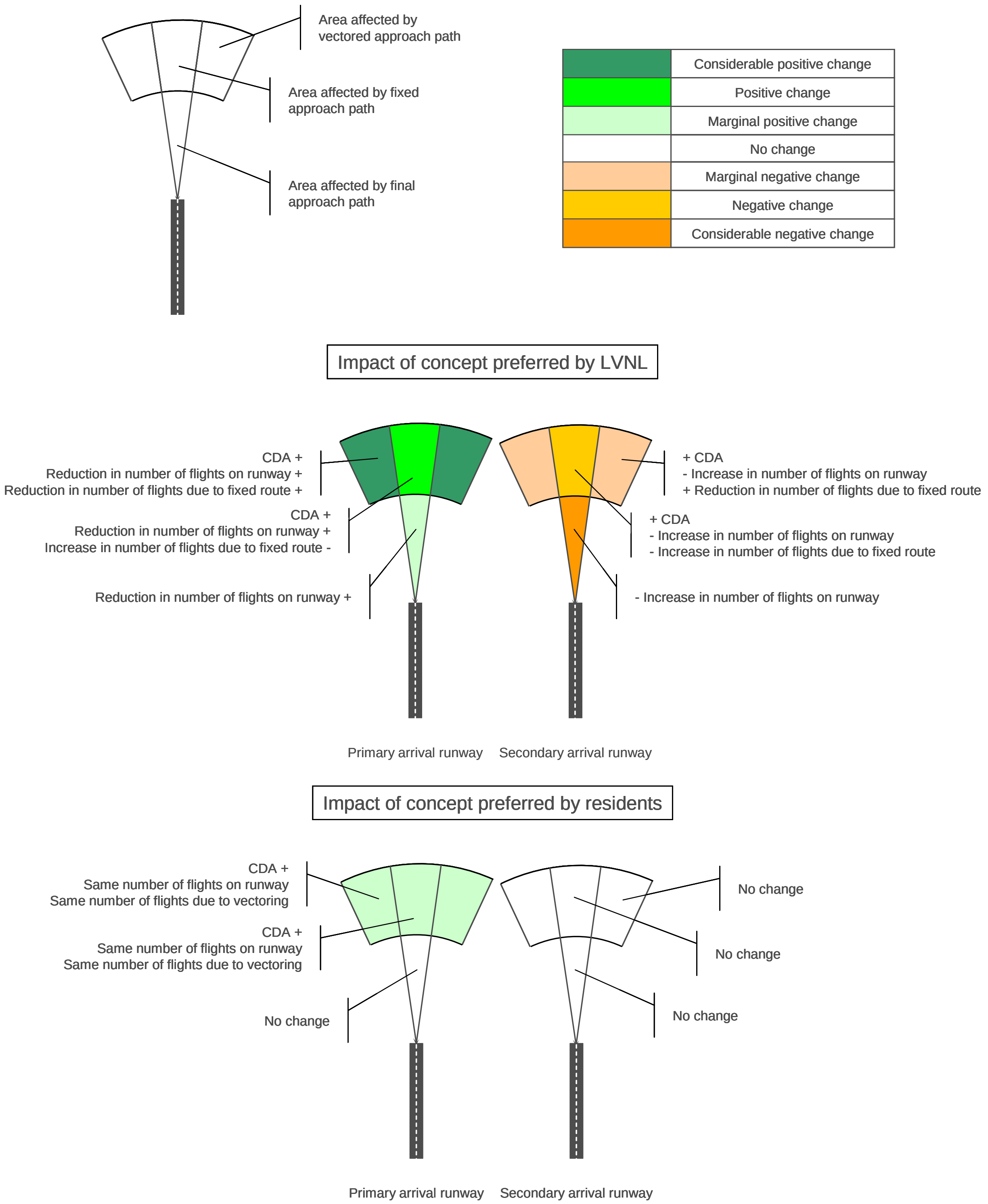


Figure 11 Noise impact of the two concepts in different areas (for the off-peak periods)

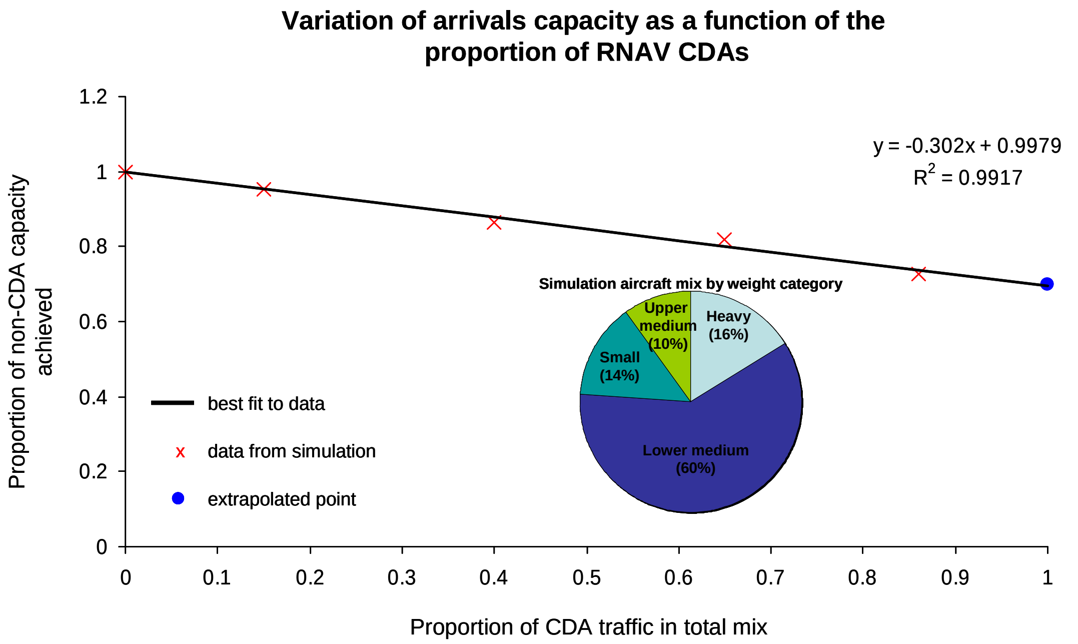
4.4.2 Capacity

4.4.2.1 The second criterion to be considered here is capacity. As described in Table 2, for the current assessment capacity is considered a requirement rather than a real evaluation criterion: we have assumed that the capacity needs to meet traffic demand with acceptable delay limits.

4.4.2.2 As a first step in the assessment, the achievable capacity of RNAV CDAs and tactical CDAs has been analysed.

<u>RNAV CDA</u>

4.4.2.3 **Basic capacity:** It is well known that RNAV CDA reduces the arrivals capacity of an airport because a larger spacing is needed between aircraft to ensure that separation minima are not breached in the absence of speed control or vectoring. Considerable work has been undertaken to assess the impact of this type of CDA on capacity in a mixed RNAV CDA/non-CDA[12] environment. The results of this research, undertaken by the Mitre Corporation's Centre for Advanced Aviation System Development (CAASD) using a simulation technique, are presented in the following figure. The points on the figure show the capacity reduction, below that of a non-CDA operation caused by inclusion of various proportions on RNAV CDA traffic. The line shows the best straight line fit to the data. The simulation work only considers a mix of up to around 86% of RNAV CDA traffic and therefore must be extrapolated to a 100% RNAV CDA traffic to give a representative view of what the overall reduction in capacity might be.



Source: CAASD/Mitre, www.ae.gatech.edu/people/jpclarke/cda/workshop6/02_CDA_120507.pdf

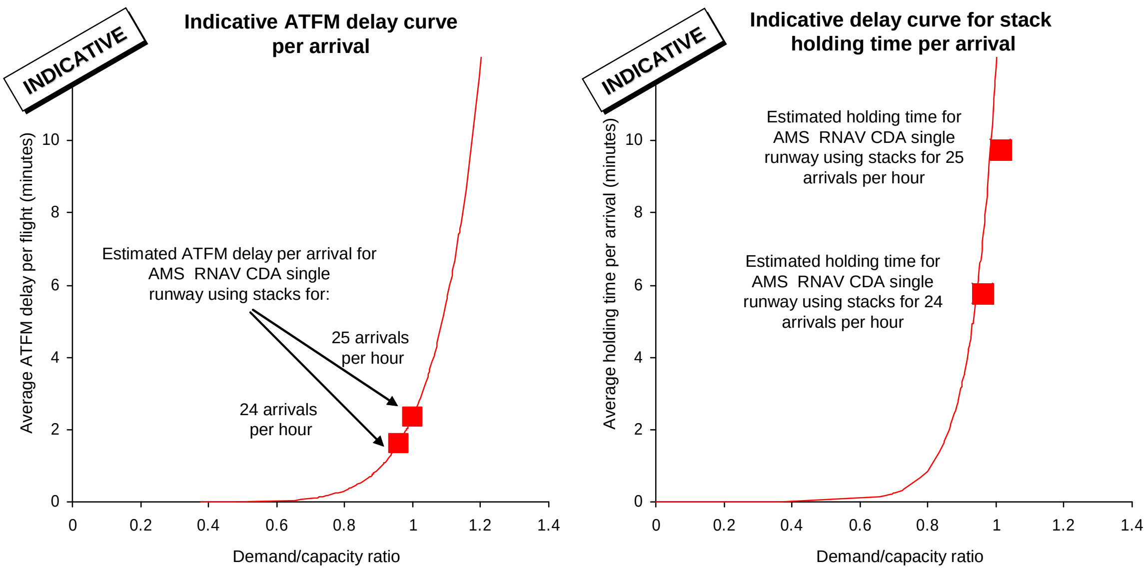
Figure 12 Reduction in capacity due to increasing the proportion of RNAV CDA arrivals in the total traffic mix

[12] www.ae.gatech.edu/people/jpclarke/cda/workshop6/02_CDA_120507.pdf

4.4.2.4 Figure 12 shows that, using this extrapolation, for a 100% RNAV CDA operation, for a traffic mix similar to that at Schiphol, the capacity is expected to be reduced to around 70% of the capacity achieved by a conventional, vectoring, non-CDA operation. For Schiphol this indicates that the 37 arrivals per hour capacity would be reduced to around 25 arrivals per hour per runway in the RNAV CDA environment. This figure is consistent with and validates the LVNL projections for single runway RNAV CDA in the current environment.

4.4.2.5 Figure 12 and the work supporting it, indicate that it is possible to operate a mixed environment in which non-CDA traffic is controlled in a conventional manner, using vectoring and speed control as necessary, interspersed with autonomous RNAV CDA traffic albeit in a two-runway environment. The capacity reduction in the mixed environment is less than the capacity reduction in the full CDA environment. In the Schiphol context, Figure 12 suggests that in a 50:50 mixed RNAV CDA/non-CDA environment, the capacity would be expected to be around 31 arrivals per hour although it is not clear that the mixed traffic could be operated onto a single runway.

4.4.2.6 **Use of holding techniques to maximise throughput:** As the application of RNAV CDA reduces runway capacity, various holding techniques, including stacks and trombones, could be envisaged to optimise the runway throughput. Holding stacks (or trombones) can be used to build a sequence of arrivals to maximise throughput. This is effectively the technique used at Heathrow to maximise throughput, albeit in a conventional environment rather than an RNAV environment. The negative impact of the use of stacks is that a buffer must be built up to enable the arrivals to be sequenced resulting in holding in stacks and, when demand is near to capacity, the risk that air traffic flow management (ATFM) restrictions will need to be applied to regulate the flow into the stacks. The following figure gives indicative estimates of the ATFM delays and stack holding that could be expected at Schiphol for an arrivals capacity of 25 per hour based on the relationships between ATFM delay and stack holding times derived for Heathrow simply as a function of the ratio of demand to capacity. The indicative relation is not dependent on any specific operational concept.



Source: CFMU, Airline data, Helios analysis

Figure 13 Indicative estimates of ATFM delays and stack holding times to support near-capacity RNAV CDA operations at Schiphol

4.4.2.7 Figure 13 suggests that for demand levels of:

- around 24 arrivals per hour, ATFM delays of an average of just under 2 minutes per inbound flight and stack holding of around 6 minutes per inbound flight might be expected. This performance would be expected to be marginally acceptable to a highly interconnected network operation such as KLM's
- around 25 arrivals per hour, ATFM delays of an average of just over 2 minutes per inbound flight and stack holding times of around 10 minutes per inbound flight might be expected. This is assumed to be unacceptable.

4.4.2.8 A demand of around 26 arrivals per hour would increase the stack holding time to over 20 minutes per flight and would be unacceptable.

Tactical CDA

4.4.2.9 Operations at London Heathrow use a combination of vectoring, speed control and holding stacks to optimise the sequencing of arrivals and maximise runway throughput. Using this technique the peak arrivals capacity at Heathrow on a single runway is around 44 aircraft per hour and averages at 41 or 42 arrivals per hour. As a consequence of these procedures, tactical CDAs are also enabled and strongly encouraged with a success rate of around 90%. This high achievement rate is facilitated by a strong campaign by BAA (the airport operator) and NATS (the air navigation service provider) to encourage aircraft operators to undertake and improve CDAs[13].

4.4.2.10 At face value and in EUROCONTROL's experience the capacity impact of tactical CDA would be expected to be negligible and then this technique would, therefore, be expected to achieve an arrivals capacity of around 37 arrivals per hour on a single runway at Schiphol and around 68 arrivals per hour on two runways. However, the Sourdine II project undertook an analysis of noise abatement procedures, including CDA, at a range of airports, including Schiphol. Part of the analysis focused on understanding the impacts of CDA on capacity[14] based on simulations using the Total Airport and Airspace Modeller (TAAM). One of the scenarios modelled, Proc IIA, was based on tactical rather than RNAV CDAs.

4.4.2.11 Sourdine II based its capacity assessment on an average airborne holding time of 10±1 minute as being acceptable. Using this criterion, the two runway capacity was determined to be around 71 to 73 arrivals per hour (see Figure 6-6 of Sourdine II deliverable D-4-1-2a). However, the holding time assumption used in this derivation, currently the one used at Heathrow, is probably too high to provide the reliability and predictability needed to ensure KLM's network integrity. Using an assumption of holding times of less than 1 minute, the capacity of two arrivals runways predicted by Sourdine II is reduced to around 61 arrivals per hour or around a reduction of 10% on the current observed arrivals rate of 68 per hour.

4.4.2.12 The capacity associated with tactical CDA might be expected to be in the range:

- for a single runway tactical CDA the capacity would be at minimum around 32 or 33 arrivals per hour and at maximum around the 37 movements per hour currently achieved

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[13] Source: EUROCONTROL

[14] 'Study on optimisation procedures for decreasing the impact of noise II', Deliverable D4-1-2a capacity results Schiphol, European Commission Project GRD2-CT-2000-30105, 14 December 2005

- for a two runway tactical CDA the capacity would be around 61 arrivals per hour at minimum and around 69 arrivals per hour at maximum assuming the runways are independent

4.4.2.13 The second bullet mentions the assumption that runways are independent. At Schiphol, runway operations typically are dependent, and a final issue to be mentioned here in relation to capacity specifically at Schiphol when operating tactical CDAs is the application during operations on parallel dependent arrivals runways. In current operations, required separation is guaranteed through vertical separation (see Figure 14 below for an example). This solution would no longer be feasible when operation tactical CDAs as vertical profiles vary, leading to a need for an alternative means of guaranteeing separation. If no such means can be implemented, restrictions may need to be applied to use of tactical CDAs on parallel runways. Any conclusions on simultaneous use of tactical CDAs on two runways need to be considered in relation to this caveat.

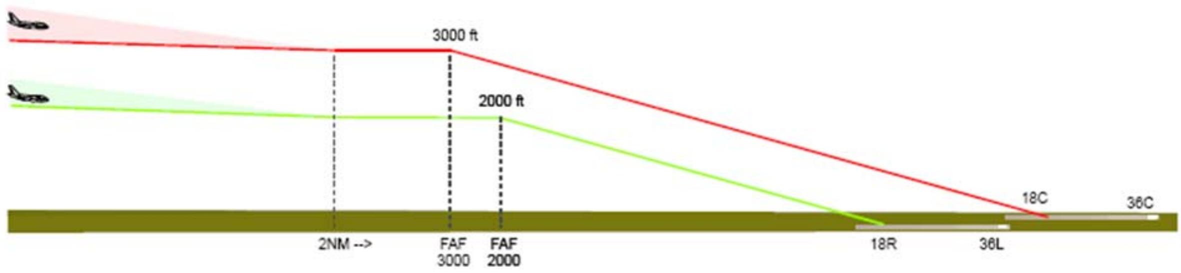

Figure 14 Illustration of vertical separation during parallel arrivals runways operations

4.4.2.14 Assuming the derived capacity figures and the same delay curves for tactical CDA as shown in Figure 13, then the delay curves in Figure 13 suggest that:

- where the demand is around 25 or 26 arrivals per hour (e.g. in the afternoon outside of arrivals peak periods), a single runway could handle the traffic with minimal airborne holding (0.2 to 0.4 minutes per flight, noting that the analysis predicts a holding time of 0.2 minutes per flight in the absence of tactical CDA). This is assumed to be acceptable

- where the demand is for around 38 to 40 arrivals (e.g. in the afternoon peak periods), the two runways could handle the demand using tactical CDAs without the need for airborne holding

- where the demand is around 60 arrivals per hour (e.g. in the morning and evening peaks), the tactical CDA technique is unlikely to provide sufficient capacity without the need for significant airborne holding and air traffic flow management delays (noting that without CDAs the demand/capacity ratio would suggest an airborne holding time of around 3 minutes for normal operations).

4.4.2.15 It should be noted that the figures quoted in the above paragraph are based on a rough rule of thumb and should be verified by more detailed analysis than has been possible during the tight timeframe of this project or through flight trials.

4.4.3 Other criteria

Safety

4.4.3.1 As indicated, safety is considered a prerequisite rather than a true assessment criterion, but different levels of effort may be required to achieve similar levels of safety in different concepts.

4.4.3.2 The measures taken to assure safety are related to and will be driven by workload and complexity.

4.4.3.3 In terms of workload, the issue was already briefly addressed in Section 2.3.3: a higher workload can be expected for both pilot and controller during parts of tactical CDAs when the flight path of each flight is defined through controller instructions and pilot implementation of these instructions, whereas in RNAV CDAs the route is pre-defined, both in the lateral and vertical sense, and will only be changed if circumstances require. However, anecdotal evidence collected by EUROCONTROL suggests that any increased workload is not viewed as significant by either controllers or pilots.

4.4.3.4 In terms of the complexity of the traffic situation, the argument is very closely related to the workload and therefore very similar: predictability of the traffic situation is high when using fixed routes, reducing complexity, whereas in tactical CDAs the traffic situation can become quite complex; see Figure 6 as an illustration of this.

4.4.3.5 Vectoring is applied safely in current operations at Schiphol, and is expected to continue to be the main concept to be used during arrivals peak periods up to 2020. However, the application of vectoring during CDA operations is slightly different from vectoring during stepped approaches, as the air traffic controller has no influence on the vertical profile of a flight and the merging of different traffic flows to a single runway becomes more difficult. In this case, London Heathrow is an example of how vectoring can still be applied safely to high intensity operations, supporting EUROCONTROL's experience that, despite the described issues, tactical CDA does not have a negative impact on safety.

4.4.3.6 A final point regarding safety in relation to operating the concepts is the complexity of changing situations during the day of operations. Currently, there are already many changes in runway use during the day as a result of the alternating peaks. By introducing a change of concept in combination with a change of runway, the impact of the change obviously becomes more significant. However, an initial view on the different possibilities does not lead to any unacceptable safety issues, but further study on this subject will be required, independent of the way forward that will be decided.

4.4.3.7 In addition to safety issues directly related to operations, the safe performance of the development and introduction phases needs to be taken into account.

Emissions

4.4.3.8 In general, CDAs will have a positive effect in fuel burn and a closely related effect on emissions. The different concepts for lateral path definition may have different impacts, but this will strongly depend on the details of the implementation, e.g. the length of the flight path in an RNAV CDA or the possibility to use longer or shorter routes when vectoring. The effectiveness of the CDA may be reduced when significant tactical vectoring is required, with related negative effects on emissions.

4.4.3.9 If capacity enhancing measures such as stacks and trombones are applied, this can have a significant negative effect on emissions as aircraft fly extra distances to allow ATCOs to optimise the sequence.

4.4.3.10 An environmental impact assessment of emissions would be required.

Reliability

4.4.3.11 Reliability has been considered in the analysis of capacity.

Predictability

4.4.3.12 For predictability, differences between the concepts are minor. The potential need for trombones and in particular holding stacks can have a negative effect on predictability though. This was already taken into account in the capacity analysis, where assumptions were made on the acceptable average amount of time spent holding stacks.

Micro-level economic impact

4.4.3.13 At the micro-level, i.e. costs and revenue of actual operations, the most significant issue to be considered is the operation of aircraft by the airlines. In this respect three issues should be mentioned:

- Fuel cost. The discussion related to fuel burn is very similar to the discussion relating to emissions: in general CDAs will have a positive effect as they reduce fuel burn, but the effects of the different concepts are similar (with potentially reduced effectiveness if tactical CDAs require significant tactical vectoring). As with emissions, need for holding or trombones will have a negative effect.
- Equipage. Aircraft will require proper equipment to enable them to fly RNAV CDAs, which leads to investment from the aircraft operators. However, this equipment is often already available in modern aircraft as its use in various phases of flight becomes more and more common.
- Connectivity. The hub operations of KLM at Schiphol airport have been mentioned several times. Failed connections, i.e. passengers that do not manage to transfer successfully from an arriving to a departing flight, can be quite costly for the airline. Therefore any operational disruptions and delays should be minimised. This needs to be considered when determining the amount of airborne holding and ATFM delay than any of the CDA options may lead to during different parts of the day.

Macro-level economic impact

4.4.3.14 As capacity has been treated as a requirement, CDAs are not considered to create a limitation to airport operation or growth and therefore the general economic impact of the airport on the region will not depend on CDA operations.

4.4.3.15 Where the different CDA concepts will have an impact is in terms of development of the areas of the region experiencing noise, i.e. the physical planning: disturbance by noise will limit the possibilities for development and therefore a concept in which noise is concentrated in a limited area is considered preferable over a concept in which noise is dispersed over a wide area.

4.5 Meeting demand

4.5.1 General

4.5.1.1 In this section, an indication is provided of the options available to meet traffic demand with the different CDA concepts, during different parts of the day.

4.5.1.2 Due to the timescales of the project, the assessment has had to be based on a number of assumptions in relation to traffic demand:

- The assessment has been based on hourly traffic. Experience shows that traffic density can vary over a one hour period (something which can be deduced from the fact that the peak periods do not match the hourly periods) and details of these variations will not be apparent when using a one-hour granularity.
- Although figures for actual hourly arrivals were used rather than planned arrivals, to incorporate the effect of actual operations, these figures were then averaged over a long period. As a result, some operational issues that may occur at a tactical level, such as bunching, no longer show up in the figures.
- Distribution of traffic growth over the day has been assumed to be proportional to the current daily profile, i.e. the same percentage of growth is applied to every hour of the day. Actual developments over the next few years may show more significant growth in some periods of the day than in others.

4.5.1.3 In areas where the conclusions of the next sub-sections are sensitive to the traffic demand, a more detailed analysis would be advisable.

4.5.2 Arrivals peaks

4.5.2.1 Figure 7 and Figure 9 combined with the capacity assessment in Section 2.2.4 show that capacity to meet peak arrivals across the day (except for the first morning peak) can mostly be provided by using two arrivals runways in conventional vectoring non-CDA operations as at present (capacity 68 arrivals per hour). It appears unlikely that up to 2020 any form of CDA could be provided during the first two morning and last evening peaks using either the tactical or the RNAV techniques without having a very significant negative impact on capacity.

4.5.2.2 From a purely capacity perspective, a <u>tactical CDA</u> operation could be applied to two runway operations during the afternoon arrivals peaks (if the issue with simultaneous use of tactical CDAs on parallel dependent runways, as described in Section 4.4.2, can be resolved) with no impact on holding. It would not, however, be possible to apply <u>RNAV CDAs</u> during these peaks.

4.5.3 Outside arrivals peaks during the day

4.5.3.1 The demand during the afternoon periods outside arrivals peaks is:

- for the 14:00 to 16:00 period (roughly the period between the two afternoon arrivals peaks), currently around 22 to 24 arrivals per hour in the summer and 22 to 26 arrivals per hour in the winter
- for the 17:00 to 18:00 hour (roughly the period between the second afternoon arrivals peak and the evening arrivals peak), currently around 28 arrivals per hour in the summer and 24 arrivals per hour in the winter.

4.5.3.2 By 2012, the demand in these off-peak periods is likely to have risen to:

- around 25 to 26 arrivals per hour during the 14:00 to 16:00 period and 24 to 28 arrivals per hour over the same period in the winter
- around 31 arrivals per hour for the 17:00 to 18:00 period in the summer and 26 arrivals per hour over the same period in the winter.

4.5.3.1.1 Comparison with the capacity figures for each of the CDA techniques, as described in Section 4.4.2, suggests that, for the periods outside the arrivals peaks during the day, over the year:

- RNAV CDA as proposed and using a single runway cannot provide sufficient capacity to meet demand with acceptable holding times/delays either now or in the future. This conclusion is relatively insensitive to the 25 arrivals per hour runway capacity ascribed to the RNAV CDA. Enhancements to the procedure would need to provide an additional 25% capacity (on top of the current 25 arrivals an hour) to enable single runway RNAV CDAs.
- A 2 runway RNAV CDA would easily provide sufficient capacity without any need for holding.
- A tactical CDA operation would provide sufficient capacity using a single runway without the need for significant holding. At worst this holding would be less than 0.4 minutes per flight in the earlier period and less than 1.3 minutes per flight in the later period whereas, at best, if tactical CDA did not reduce capacity (as at Heathrow and EUROCONTROL's experience in trials), no additional holding would be introduced. This approach would have the consequence of dispersing noise around the flight path.

4.5.4 Operations after the last arrivals peak of the day

4.5.4.1 Currently arrivals demand after the last arrivals peak of the evening and before the first arrivals peak of the following day is consistently below 25 arrivals per hour, so there appear to be no reasons that RNAV CDAs cannot be applied during this period using a single runway in the (near) future. This would require development of new routes and procedures as the existing night time RNAV CDA procedures can not be applied outside the 23:00-06:00 period without change. These new routes and procedures should probably be developed in such a way that they can be applied during both evening and night, so that a single set of procedures and routes can be applied for the full period, which is preferred over a situation with two different sets, which would be more complex.

4.5.4.2 By 2012, the arrivals demand in the two hours after 20:00 is likely to have risen to around 26 and 25 arrivals per hour respectively, at least in the summer period. Use of holding techniques in the second of these hours might be acceptable to enable RNAV CDA onto the single runway (ATFM delays would be expected to be around 2 minutes per arrival on average and stack holding/trombone delays would be expected to be around 10 minutes per arrival). However, the impact of this holding would be minimised as it occurs at the end of the day, after the last departures peak, but with the potential consequence of distributing some additional noise into the following hour.

4.5.4.3 Holding delays at the first hour after the last arrivals peak with a 26 arrivals demand level would likely be too high to be acceptable. However, this could be dealt with by applying a scheduling limit of 25 arrivals for this hour (affecting only the summer season).

4.5.4.4 In general, the starting time of the use of RNAV CDAs in the evening should probably be decided on a tactical basis, i.e. when traffic allows, rather than based on a fixed time. In this way, any overflow from the final arrivals peak can be handle efficiently and without restrictions.

4.5.4.5 This option is sensitive to two future developments. Firstly, traffic demand is based on assumptions as described in Section 4.5.1. Secondly, RNAV CDA capacity is expected to grow over time as more experience is gained. The impact of these two developments needs to be taken into account when defining the details of the CDA option to be applied.

4.5.4.6 It might be possible to manage arrivals using RNAV CDAs onto a single runway, similar to the evening, in the early morning. However, this period at the start of the day has a very high sensitivity in terms of disruptions that could have knock-on effects during the rest of the day.

4.5.5 Summary

4.5.5.1 With some minor rescheduling of demand and using holding techniques, it should be possible to apply a single runway RNAV CDA technique in the evening and potentially early morning hours, to meet demand levels from those experienced at present to the time that the assumed future movement cap is reached. This would be in addition to the specific night time RNAV CDA procedures that are already in use in the 23:00-06:00 period. However, it must be accepted that the boundaries of this period are not fixed and must be adjustable on a tactical, operational basis to, for example, cope with increased demand after 20:00 to cope with the knock-on effects of delays from earlier in the day and also in the early morning to account for the early occurrence first arrivals peak. It must also be acknowledged that delays in the early morning peak will have a severe knock-on effect throughout the day from which it might not be possible to recover.

4.5.5.2 Single runway RNAV CDA cannot provide the capacity needed to meet demand during the off-peak arrivals periods in the afternoon, either now or in the future. The options to meet this demand are:

- enhancement of capacity for RNAV CDA through technological or operational enhancements (requiring a 25% capacity increase). The timeframe required for the development of such enhancements is not known
- use of two runways for RNAV CDA
- use of a mixture of RNAV CDA and conventional vectoring/stepped approaches on a single runway (likely to add and unacceptable degree of complexity to the operation)
- use of tactical (vectoring) CDA on a single runway
- continuation of the conventional vectoring, non-CDA procedures used during the peak periods but using a single runway.

4.5.5.3 These conclusions are summarised in the following figure.

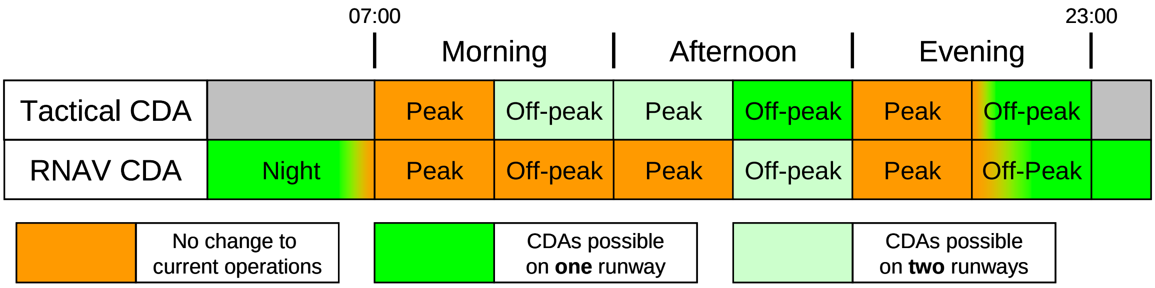

Figure 15 Overview of CDA options during the day

A Potential future capacity enhancing developments

A.1 **Use of new technology to maximise throughput:** In the future, new technology applications, particularly airborne separation assistance systems (ASAS) are likely to be available to allow aircraft to optimise their separations and hence maximise runway throughput autonomously. Such a system – SafeRoute[15] – is being implemented on the UPS B757 fleet operating from Louisville, Kentucky. However, the gains achieved will be dependent on the proportion of aircraft that are equipped as well as the traffic mix (light, medium, heavy). This type of system will undoubtedly increase the single runway RNAV CDA capacity above 25 arrivals per hour.

A.2 **Use of new ATC tools to optimise timely delivery of aircraft into AMS TMA - SARA tool:** LVNL is working with its partners[16] on a project aiming to deliver a decision document for the LVNL process “Change ATM System” on the Speed And Route Advisor (SARA) function in the main ATM System (AAA). Such a function would allow accurate delivery of arrival traffic at the IAFs for Schiphol at planned arrival times by upper area controllers based on advisories in speed and routing. The SARA advisories would take into account traffic conditions, aircraft performance, coordination with neighbouring sectors and atmospheric conditions in order to allow for their predictable execution with minimal adjustment. To achieve this objective the project aims to develop, evaluate and demonstrate an operational concept supported by SARA function. This tool development fits well into the European strategic SESAR plans and has a potential to contribute to increase of the RNAV CDA achievement rates and their adverse impact on capacity by optimising the sequence of aircraft in more strategic, rather than tactical way.

A.3 **Capacity enhancement using new procedures:** The EUROCONTROL Point Merge[17] concept aims to optimise and harmonise arrival operations using existing technology and therefore is the closest to be operationally available. Point Merge is based on a specific P-RNAV route structure that is made of a point (the merge point) with pre-defined legs (the sequencing legs) equidistant from this point that should be used for path shortening or stretching. The sequence is achieved with conventional direct-to instructions to the merge point. Open-loop vectoring should only be used to recover from unexpected situations. As Point Merge relies on existing technology, namely P-RNAV and AMAN (arrival manager) metered traffic, it can be implemented in the short term (by 2012, for example). It is also a building block for medium and long term developments, such as 4D trajectory management, in the context of SESAR. The Point Merge is currently being considered for implementation at Oslo, Rome and Dublin. It could help to maintain current runway throughput (during longer periods with higher accuracy) and minimise the environmental impact by enabling higher achievement rates of RNAV CDAs. The feasibility of using this concept in the AMS TMA would need to be elaborated in more detailed study.

A.4 **The magnitude of the capacity and achievement rate improvements** and when exactly these tools and concepts will be available is not known. The likely

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[15] www.flttechonline.com/Current/L-3%20Says%20ACCS%20SafeRoute%20System%20Set%20for%20Certification.htm

[16] Boeing, EUROCONTROL, Maastricht UAC, Martinair, Transavia

[17] http://www.eurocontrol.int/eec/public/standard_page/proj_Point_Merge.html

order of availability for implementation between 2012 and 2020 might be as follows: Point Merge, SARA, SafeRoute (ASAS).