DFS Aviation Services

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REVIEW

of

"*Risk analysis of runway combination changes at Schiphol airport* and the *Fourth runway rule*"

Customer: Dutch Ministry of Infrastructure and Water Management

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ABBREVIATIONS

This section details the abbreviations and acronyms used throughout this review document:

Acronym	Meaning
AAS	Amsterdam Airport Schiphol
ABL	Analysebureau luchtvaartvoorvallen / Aviation Occurrence Reporting Bureau
A-CDM	Airport Collaborative Decision Making
AMAN	Arrival Manager
APC	Apron Control
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
DAS	DFS Aviation Services GmbH
DFS	Deutsche Flugsicherung GmbH
ECCAIRS	European Coordination Centre for Accident and Incident Reporting Systems
EU	European Union
FC	Flight Crew
FTS	Fast-Time Simulation
ICAO	International Civil Aviation Organization
IRM	Integrated Risk Management
ISMS	Integral Safety Management System
ISO	Integral Safety Office (operational function of the ISMS)
LOSA	Line Operations Safety Audit
LVNL	Luchtverkeersleiding Nederland / Air traffic control the Netherlands
NNHS	Nieuw Normen- en Handhavingstelsel / New standards and enforcement system
OTP	On Time Performance
OVV	Onderzoeksraad voor Veiligheid / Dutch Safety Board
ROT	Runway Occupancy Time
RP	Reference period
SMS	Safety Management System
TOP SAG	TOP Safety Action Group
TTO	Target Time Over
VNV	Vereniging Nederlandse Verkeersvliegers / Association of Dutch Pilots

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1 MANAGEMENT SUMMARY

In this document DFS Aviation Services GmbH presents the results of the review carried out on the process, methodology, findings and actions of previous analyses and mitigations regarding operational risks introduced by the significant number of runway combination changes at Schiphol airport, as well as the impact brought by the 4th runway rule to those risks.

The *Risk analysis of runway combination changes at Schiphol airport* (referred to as *Risk analysis*) was entrusted to the company MovingDot by the Integral Safety Management System (ISMS) and came to address some of the concerns of the Dutch Safety Board (OVV) regarding air traffic safety at Schiphol.

The *Risk analysis* confirms that current runway combination changes are a source of safety risks at the airport. However, the majority of these risks are acceptable. Only the risk of *operational complexity and workload* is recommendable to be reduced. This was confirmed by a 'first' external review carried out by Helios, who made recommendations such as to better consider future growth in the analysis or to assure risk reduction by implementing risk mitigation actions.

A series of measures were defined in a *Risk reduction action plan* (referred to as *action plan*) performed by an ISMS taskforce led by LVNL.

The Risk analysis comes to provide evidence that in-progress and future endeavours in the *action plan* are going to have a positive impact, not only on the risk of *operational complexity and workload* (slightly between the 'acceptable' and the 'tolerable' region of the Risk Matrix), but also on the rest of detected risks of runway combination changes.

LVNL shows efforts to accommodate the requirements of local residents by reducing the use of a fourth runway. The measures to that purpose have been defined in *"The fourth runway rule and the Schiphol operations"* (referred to as *Fourth runway rule*), some of them applicable from summer 2019.

This review addresses the interest of the Dutch Ministry of Infrastructure and Water Management (referred to as *Ministry*) to ascertain the activities carried out to manage safety risks in the scope of runway combination changes and fourth runway operations.

The interest is also drawn to make sure that risks keep being controlled after implementation of the measures. This includes the assurance of compatibility of measures between the *action plan* and the *Fourth runway rule*. In essence, that Safety remains uncompromised in a future at Schiphol, including a context of traffic growth.

The results of the DFS Aviation Services GmbH review show that both the *Risk analysis* and *action plan* have followed an adequate methodology; that safety risks of runway combination changes are acceptable (only *operational complexity* in the 'tolerable' area), and that current processes in place assure controllability of future risks.

Some of the measures in the *action plan* have already proven a positive safety impact on reducing risks. Future control is assured by means of current processes to manage safety risks (e.g. change management) and continuous monitoring (e.g. KPI/trends), and the actions thereby.

Within the *Risk analysis*, the 4th runway rule was just a reason (part of the 'noise abatement regulations') for runway changes, and hence a parameter to determine the risk. The risks that may arise from future measures/solutions (mid-term measures) to reduce the use of the fourth runway are also kept under control by means of the processes in place at LVNL to manage changes to the functional system.

The measures in the *action plan* and the *Fourth runway rule* need to be considered complementary, as together they intend to reduce the use of a fourth runway, while reducing the operational complexity and increasing existing capacity.

2 INTRODUCTION

2.1 BACKGROUND

On April 2017 the Dutch Safety Board (Onderzoeksraad voor Veiligheid, OVV) published the report "Schiphol Air Traffic Safety", which was preceded by an investigation to identify vulnerabilities in the safety system around Schiphol. During its investigation, the OVV detected that there were safety risks that needed to be "tackled integrally and systematically", and suggested to *reduce the number of runway configuration changes*. In addition, they pointed out that no party at Schiphol had taken responsibility in the past for the integral safety of air traffic at and around the airport. The role of the Ministry was also questioned for not acting as the party with final responsibility, and missing the holistic view of aviation safety at Schiphol. Following the recommendations of the report, the sector parties (operational stakeholders) at Schiphol built the ISMS to bring safety management at Schiphol to an integral level.

As part of its tasks, the new ISMS sought to tackle OVV concerns on the number of runway configuration changes. Because this was not available yet, first an assignment to perform a study on the safety risks of these changes was given to an external party (MovingDot), which produced the *Risk analysis of runway combination changes at Schiphol airport*. Contrary to the OVV report, the *Risk analysis* showed no major concerns. This report was therefore then submitted for an independent review by another external consultant (Helios). Inputs from that review were taken into account and the *Risk analysis* was accordingly updated. Although the risks were classified as *acceptable* (and one partly in the *tolerable* region) in the ISMS Risk Matrix, the decision was made to develop a *Risk reduction action plan* to substantiate future reduction of detected safety risks.

The OVV also made clear its preoccupation with regards to the safety effects that may be imposed by the 'new standards and enforcement system' (NNHS) in effect at Schiphol airport, which contains the so called '4th runway rule'. The OVV states that *"the Ministry leaves the role of safety watchdog in the Schiphol Community Council to LVNL"*. The NNHS contains agreements between the sector and the Schiphol Community Council about the strict noise preferential runway use system. The Ministry has proposed that future growth of air traffic at Schiphol will depend on a trade-off between noise abatement and network quality, which may include aspects such as safety or residents health. It is however yet uncertain to what extent all those aspects will play a role.

Following the OVV concerns, the Ministry intends to further improve oversight of air traffic safety at Schiphol. At the beginning of summer 2019, LVNL issued the document *"The fourth runway rule and the Schiphol operations"*, containing sector measures *"to reduce the number of aircraft movements on the fourth runway in 2019 compared to the preceding years and to comply completely with the fourth runway rule in 2020"*. Within this context, DFS Aviation Services has been entrusted by the Ministry with the task of making a new independent review, of both the *Risk analysis* (initiative from ISMS) and *"The fourth runway rule and the Schiphol operations"* (LVNL). The Ministry seeks for an external opinion that provides a critical view, assurance and recommendations as to whether: the *Risk analysis* has been performed in a coherent and concise manner; safety risks have been properly detected and managed; traffic growth is compatible with current safety risks; and additional measures to reduce the use of the 4th runway take account of their impact on the safety risks related to runway combination changes.

2.2 PROCESS

The review has been performed based on the following documents:

- *Summary Schiphol Air Traffic Safety*; Onderzoeksraad voor Veiligheid (OVV), Dutch Safety Board; final version; The Hague (Netherlands), April 2017
- *Decision sheet "Joint sector TOP SAG 02.07.18, Runway Changes, The acceptability of the risk"*; Jasper Daams, Integral Safety Office (ISO); version 0.4; Document number: TOP SAG 201802; 02 July 2018

- *Decision sheet "Joint sector TOP SAG 03.12.18, Review runway combination changes";* J. Daams (ISO); version 2.0; Document number: TOP SAG 201813DS; 03 December 2018
- *Review of "Risk Assessment Runway Change Schiphol"*, Review for Schiphol airport; Helios; final version; Reference number P2651D001; Farnborough (United Kingdom), 17 December 2018
- *Decision sheet "Joint sector TOP SAG 22.03.19, Runway Combination Changes";* J. Daenen; version 4; Document number: TOP SAG 201907DS; 22 March 2019
- *Risk analysis of runway combination changes at Schiphol airport, Operational Impacts*; MovingDot; Document ISMS-201803; version 1.2; 23 April 2019 (referred to as *Risk analysis*)
- *Runway combination changes Schiphol, Risk reduction action plan*; ISMS Taskforce, Document ISMS-201909R; final version; 27 May 2019 (included in Risk analysis, referred to as *action plan*)
- *Decision sheet "Joint sector TOP SAG 20.06.19, Runway Combination Changes";* J. Daenen (measures), J. Daams (risk assessment); Document number: TOP SAG 201914DS; 20 June 2019
- *The fourth runway rule and the Schiphol operations, A reflection on measures and effect*; LVNL, Reference number SCM/CMA/6000; version 1.0; 19 July 2019 (referred to as *Fourth runway rule*)
- *Schiphol Safety Improvement Covenant*, Convenant veiligheidsverbetering Schiphol; Ontwikkeling integraal veiligheidsmanagementsysteem Schiphol en Analysebureau Luchtvaartvoorvallen; 02 July 2018 (referred to as *Covenant*)

In addition, two meetings were held:

- 28.08.2019 – *The Hague*, DFS reviewers and representatives of the Ministry. Discussion on the scope and objectives of the review.
- 12.09.2019 – *LNVL at Schiphol*, DFS reviewers and representatives of the Ministry, LVNL, ISMS and MovingDot. Chronological course of events and documentation produced; discussion about the process of elaboration of the Risk analysis; discussion about specifics of ATC operations with runway combination changes and the use of a fourth runway.

2.3 TERMS OF REFERENCE

Expected issues to be addressed in the review are presented as questions in the 'Request for quotation' document from the Ministry:

Runway combination changes

- Has the analysis been performed in a good, solid manner in accordance with the applicable (international) methodologies?
- Have all relevant stakeholders with an SMS been interviewed and have they properly been involved in the analysis?
- Have all concerns, points of attention and recommendations from the Dutch Safety Board regarding the safety impact of runway combination changes been properly included in the analysis of MovingDot and the subsequent review by Helios?
- Are additions to the analysis required in this context?
- Is it ensured that the risks remain controlled, also when there is growth in air traffic?
- Are the identified risks sufficiently and adequately covered by the proposed measures and solutions in the risk reduction action plan?
- Have the solutions been properly mapped in terms of effectiveness, costs / benefits, feasibility, support, enforceability, sustainability and side effects?

- Are other measures and solutions conceivable within the current operational concept that could reduce the identified risks?

Fourth runway rule

- What measures are necessary according to the ISMS parties to comply with the 'fourth runway rule'?
- Have the safety risks of these measures been adequately identified?
- Are there going to be additional measures implemented to manage these risks?

Interdependence

- Has an adequate assessment been made as to whether the measures related to compliance with the 'fourth runway rule' have a potential (negative) effect on the risks associated with runway combination changes and vice versa?
- Have additional measures been taken to manage these risks?

3 RISK ANALYSIS OF RUNWAY COMBINATION CHANGES (*RISK ANALYSIS*) AT SCHIPHOL AIRPORT AND RISK REDUCTION ACTION PLAN (*ACTION PLAN*)

This section reviews and evaluates the *Risk analysis* carried out by MovingDot. On the one hand, it evaluates (subsection 3.1) how the *Risk analysis* takes account of the concerns, points of attention and recommendations of the OVV drawn in the "Schiphol Air Traffic Safety" report. On the other hand, a review is made (subsection 3.2) of the process itself used to carry out the risk analysis, from the methodology applied, the process used to manage the safety risks, and up to the determination of the applicable risk reduction measures in the *action plan*.

Note that Helios already did a first review of the *Risk analysis*. The elements considered to still be valid are going to be mentioned, as well as disagreements with their viewpoint. We acknowledge that the recommendations given by Helios and the *action plan* have been thereafter implemented and developed respectively in parallel. Our review is therefore based on the latest version of the *Risk analysis* report.

3.1 SAFETY CONCERNS, POINTS OF ATTENTION AND RECOMMENDATIONS FROM THE DUTCH SAFETY BOARD (OVV)

3.1.1 Complexity of operations

The OVV investigation detected a series of circumstances as a source of complexity of operations at Schiphol, e.g. *"large number of daily runway configuration changes, traffic crossing the take-off and landing runways each day, deviations from procedures to handle the traffic, and capacity shortages at air traffic control"*[1].

The *Risk analysis* evaluates the safety risks brought by the runway combination changes. In a first step, a research was conducted to gather relevant information. Runway usage data, A-CDM data and event data were collected to identify causal or contributing factors related to runway changes. In addition, the operational stakeholders provided their input (by means of interviews) on the issues that affect them with regards to runway changes.

The analysis of these elements showed that, indeed, the *operational complexity* associated with runway combination changes at Schiphol has a slight impact on safety risks. In fact, and whereas the rest of risks derived from hazards are acceptable, the hazard "airport and operational complexity and workload" is the single one which is partly placed between the 'acceptable' and 'tolerable' region in the ISMS common risk matrix. Such was a decision taken in a workshop by the representatives of the involved stakeholders.

The *Risk analysis* also takes consideration of the circumstances 'adding' complexity to the operation at Schiphol. These are in many cases large in scope and cannot be addressed with simple actions or mitigations. For instance, it is well known the lack of airport infrastructure at Schiphol: *"LVNL experiences the manoeuvring space at the airport as limited due to a lack of aircraft stands. Amsterdam Airport Schiphol recognises that the existing tight infrastructure increases complexity and limits air traffic and safety. The Association of Dutch Pilots (VNV) also notes that airborne operations are becoming more complex […]"*[2]. The OVV adds in its summary report in English: *"Schiphol is approaching the limits of its ability to handle air traffic safely within the current operational concept"*[1]. Hence, the *Risk analysis* is performed within the current whole context of operations, and bearing in mind the restrictive elements beyond its control.

[1] Summary Schiphol Air Traffic Safety, *Consideration*, p. 5
[2] Translation Tight space (Krappe ruimte) in Chapter 2, Veiligheid vliegverkeer Schiphol, Onderzoeksraad voor Veiligheid (OVV), The Hague, April 2017

Unlike the first review of the *Risk analysis* by Helios, there are at this point specific mitigation measures defined in the *Risk reduction action plan*. These measures reduce the risks related to "airport and operational complexity and workload". However, they are also applicable to the rest of risks identified by the involved stakeholders when doing the risk analysis. The applicability of mitigations is also analysed within the current operational context; taking as baseline the yet unchanged scenario. During the Risk analysis, a first risk matrix was drawn to show the risks of identified hazards, and later a second one was built to reflect the expected risk reduction (after mitigations). The latest risk matrix shows a shift of operational complexity, as well as other risks, towards the 'acceptable' region (Figure 5).

3.1.2 Increase in the number of events since 2014

One of the concerns of the OVV is related to what they call an *"increase in the number of significant incidents"*[1]. This is also covered in the Risk analysis. As part of the *Data derived observations*, the analysis provides a quick view on runway changes related events stored in ECCAIRS at Schiphol for the period 2012-2017. The analysis detected 71 events. It is important to highlight that these do not represent actual incidents; they are events varying from 'no safety impact' to 'limited safety impact'. Therefore they do not reflect in any case a catastrophic or significant outcome.

When the OVV states an *"increase in the number of significant incidents"*[1], it is to understand that the term 'significant' could be an allusion to an increase on the amount of reported incidents in the previous years, as it does not fit with common understanding of the concept 'significant incident'. An example of description of a significant incident can be found in current applicable Reg. (EU) 1035/2011[3] [4]. The data provided in the *Risk analysis* are far from proving the existence of significant incidents.

The data does show there has been a noticeable increase in the number of occurrence reports related to runway changes since 2014. This is not a proof of increase of the so called 'incidents' in the OVV report. Operational stakeholders have made efforts in the last years to promote a positive safety culture in their organisations as to create a climate of trust that improves the occurrence reporting systems. It is then not surprising that organisations show an improvement in the number of reports received. This improvement is particularly noticeable since 15 November 2015, when the mandatory reporting system of aviation events introduced by Reg. (EU) 376/2014[5] became effective. It is unknown if OVV have based their assumption on other kinds of reported or assessed incidents, which is unlikely since the introduction of the mandatory reporting by regulation.

3.1.3 Air traffic increase and future levels of safety

The OVV shows concern for the impact of air traffic increase on safety. In that sense, Helios review recommended to take the future growth of Schiphol into the analysis as part of the 'hazard identification and risk assessment process'. We must differ in that sense. This is not a traditional risk assessment for changes to the functional system, in which a future scenario or situation is taken into account to provide assurance of safety of a change. In this case the *Risk analysis* evaluates the risks of runway changes in the current operational scenario.

Helios recommendation to consider future traffic growth was incorporated when doing the *Risk reduction action plan*. In this report the ISMS taskforce (led by LVNL) provides historical/statistical data to prove a declining trend on the runway (combination) changes and late runway changes given

[3] Regulation (EU) 1035/2011 of 17 October 2011 laying down common requirements for the provision of air navigation services.
[4] Significant incident in Regulation (EU) 1035/2011: *"Significant incident involving circumstances indicating that an accident, a serious or major incident could have occurred, if the risk had not been managed within safety margins, or if another aircraft had been in the vicinity"*.
[5] Regulation (EU) No 376/2014 of the European Parliament and of the Council of 3 April 2014 on the reporting, analysis and follow-up of occurrences in civil aviation.

to pilots. They also justify the current stability of the operation and sustainability of the capacity at Schiphol. The measures introduced in the action plan aim at maintaining this stability. In addition, the *Risk analysis* emphasizes that *"no significant traffic growth is foreseen […] in the foreseeable future"*[6]. We agree with the fact that a significant traffic growth cannot take place above 500.000 air traffic movements as per current restrictions through 2020, which would not make much difference with current operational scenario. Besides, the *Risk analysis* justifies that *"Should there be (significant) growth, the existing process for determining declared capacity ensure that potential safety impacts are considered"*[6].

However, the means used to demonstrate future levels of safety are not fully predictable. The analysis of traffic growth complies in general terms with the description of a 'predictive' analysis, but it is somehow more 'descriptive'. Whereas a predictive analysis as per ICAO SMM 4th Edition implies to *"extract information from historical and current data and use it to predict trends and behaviour patterns"*[7], the descriptive statistics *"are used to describe or summarize data in ways that are meaningful and useful"*, *"tools such as tables and matrices, graphs and charts and even maps are examples of tools used for summarizing data"*[8].

We can see that the figures provided in the action plan[9] (e.g. average amount changes in runway combination per day, percentage of Schiphol outbound flights with a runway change) show a positive trend within the last years. However, there is no certainty that trends are going to be the same during and after implementing the mitigations in the *action plan*. Assurance of future safety levels is assured by means of monitoring the relevant KPIs (e.g. number of late runway changes), and taking required actions if needed. At the same time, and according to applicable European regulations, each change the functional system has to be assessed individually by each operational stakeholder to provide assurance that risks remain to an acceptable level.

The *Schiphol Safety Improvement Covenant* (referred to as *Covenant*) also claims that *"within the framework of the ISMS, safety is analysed in its entirety by the sector parties in the event of major changes"*[10]. Additionally, the ISMS itself aims to *"[…] monitor the safety risks that affect several sector parties operating at Schiphol, for example by means of […] - joint prevention or control of the risks identified and analysed; - the evaluation of the effectiveness of the measures taken and, if necessary, the updating of the measures"*[11].

3.1.4 Human factor concerns related to high workload/pressure and complex, dynamic operations. Both air traffic controllers and pilots are mentioned

The *Risk analysis* does not hide the fact that frequent runway combination changes might be seen as a contributor to complexity and workload for air traffic controllers (ATCOs), as well as for flight crew (FC) during critical flight phase (approach, take-off preparation). The analysis on event data shows that human factors are identified as being a causal or contributory factor in events associated with runway changes: *"Crew error and workload account for a noticeable portion of the identified effects"*[12].

Nonetheless, findings in the *Risk analysis* state that runway changes are not considered an issue for pilots as long as they are timely made aware of them. Likewise, ATCOs are already used to runway changes procedures as part of their routine. However "*LVNL supports the conclusion that frequent runway combination changes poses a challenge for the operational staff, whose main consideration*

[6] Risk analysis, *5.5. Resilience* in '5. Risk analysis', p. 37
[7] *6.2.3 Predictive analysis*, ICAO Safety Management Manual (SMM), Fourth Edition, 2018, p. 6-3
[8] *6.2.1 Descriptive analysis*, ICAO Safety Management Manual (SMM), Fourth Edition, 2018, p. 6-3
[9] Risk analysis, K.5. Mitigations in 'Annex K. Risk reduction action plan', p. 109-113 & Action plan, 4. Mitigations, p. 26-31
[10] Article 9. Integral safety analysis (1), Convenant veiligheidsverbetering Schiphol – Ontwikkeling integraal veiligheidsmanagementsysteem Schiphol en Analysebureau Luchtvaartvoorvallen, 02-07-2018
[11] Article 6. ISMS (c), Convenant veiligheidsverbetering Schiphol
[12] Risk analysis, *4.2.3.3. ABL event data* in '4. Data and stakeholder-based findings', p. 27, 28

is to maintain a stable and predictable flow of traffic"[13]. At the end of the analysis there were three main areas uncovered requiring attention: runway use stability, runway change (clearance) timing, and workload/human error. These areas were collectively tackled by the measures defined in the *action plan*.

Regarding the workload/human error area, and besides the rest of planned measures in the *action plan*, a better timely coordination with flight crew can be achieved, for instance, by means of *Programs aimed at increasing joint awareness*; another example given is that maintenance and improvement of operational stability by LVNL include 'system upgrades' on *AMAN* and *A-CDM* to improve the planning processes[14]. All in all, the proposed measures aim at reducing complexity and workload to humans involved in operations.

3.1.5 The need to tackle safety issues in an integrated manner between the operational stakeholders and the role of the Ministry

Based on OVV recommendations, the key operational stakeholders at Schiphol have built the ISMS and taken note of the concerns regarding the current number of runway configuration changes. The *Risk analysis* is a singular initiative to understand the level of risk taken by the same operational parties. We perceive this as an action to contradict some conservative assumptions made by OVV and/or substantiate an acceptable level of safety within the current operational context. Although integration is not exempt from difficulties, there is so far no denying that the action taken is an enviable sign towards a better integration of stakeholders. The *Risk analysis* shows data inputs from airlines, ATC and airport operator; the common risk matrix was the result of a joint decision-making process and the results of risk workshops were commonly agreed.

On the other side, the Ministry has been singled out for not playing the role of ultimate responsible and not having the overall picture of safety at and around Schiphol. By seeking for an external review of the *Risk analysis*, and at least in this matter, the Ministry shows intentions to take part in this process of management of risks, as supervisor for the traffic growth and accountable for the maintenance of air traffic safety at Schiphol.

3.2 RISK ANALYSIS REVIEW

3.2.1 Methodology

Helios opened a debate on the name given to the *Risk analysis*, as to whether call it better 'analysis' than 'assessment'. We do not completely share the opinion that a traditional safety risk assessment as per ICAO SMS methodology was not held. The study is not only an analysis of historical data (statistics, events). MovingDot also conducted interviews with operational stakeholders (airlines, airport, ATC), and took Helios' recommendations into account to add the inputs of foreign/non-home based carriers. Subsequently, the *Risk analysis* was followed by the *Risk reduction action plan*, which detailed the mitigations measures applicable to the detected risks. At this point, the process followed to perform the *Risk analysis* is closer to the Safety Risk Management process as per ICAO SMS, based on "*hazards identification*, *safety risk assessment*, *safety risk mitigation* and *risk acceptance"*[15].

The ICAO Safety Management standards are applicable to aviation stakeholders individually. The ISMS does not behave as a single entity with developed safety risks assessment procedures. They

[13] Risk analysis, *K.3. Background* in 'Annex K. Risk reduction action plan', p. 89 & Action plan, *2. Background,* p. 5
[14] Risk analysis, *K.5. Mitigations* in 'Annex K. Risk reduction action plan', p. 113 & Action plan, *4. Mitigations*, p. 31
[15] *2.5. Safety Risk Management*, ICAO Safety Management Manual (SMM), Fourth Edition, 2018, p. 2-10

provide a joint approach to safety risks. The ISMS has modelled a common Risk Matrix[16] where the parties plot the results of assessments once they have reached an agreement. This sustains the claim that the system is closer to ICAO standards than previously expressed by Helios. The results of the *Risk analysis* were discussed in a workshop of the ISMS partners to determine the risk levels and place them in the matrix. This is a qualitative process, which does not deviate in any case from the standard: *"Safety risk assessments sometimes have to use qualitative information (expert judgement) rather than quantitative data due to unavailability of data. Using the safety risk matrix allows the user to express the safety risk(s) associated with the identified hazard in a quantitative format"*[17]. In fact, the *Risk analysis* is not missing the quantitative data. The qualitative assessment is supported on both historic data and expert judgement.

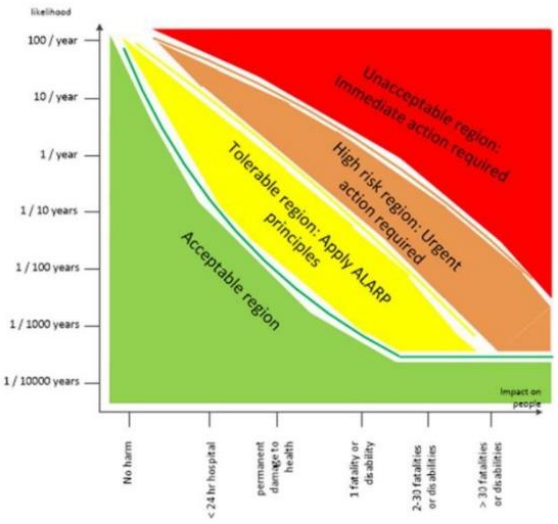

Figure 1. Common Risk Matrix for joint sector ISMS

In line with ICAO SMM 4th Edition, the *Risk analysis* performed, and the initiative itself to build an ISMS is in line with expected future developments in the aviation sector with regards to an Integrated Risk Management (IRM). This claims that a *"successful risk management in aviation should aim for overall risk reduction in the system, including all of the involved functional systems"*, which is achieved through *"the quantitative and qualitative analysis of both the inherent risks, and the effectiveness and impact of sector-specific risk management processes"*[18].

3.2.2 Management of Safety risks

As part of their Safety Management Systems (SMS), aviation stakeholders perform studies in which they apply a safety risk management process when doing management of changes; the so called *safety case* or *safety assessment*. The organisations generally gather the required information to support their assessment from either internal sources or by requesting other providers impacted by the change (e.g. data, workshops). Although the information can come from different sources, the study is performed by a single entity.

As aforementioned, the *Risk analysis* does not address a specific change; it is rather a holistic picture of the acceptability of existing risks related to runway combination changes. The OVV concerns address therefore a broader scope of risks than just those of a single stakeholder. This comes to justify the need for a joint analysis which includes the main three main contributors to operations: airlines, airport and ATC. As Helios suggests, additional stakeholders could have been included (e.g. ground movers, runway inspection car drivers, maintenance staff). However, our viewpoint is that the airlines, airport and ATC bear the biggest burden of the safety risk, and have the main resources to provide appropriate mitigations. The solutions provided in the *action plan* are an enabler to reduce the risks of runway changes by means of improving operations.

The initiative for such *Risk analysis* was easily facilitated by the recent creation of the ISMS. This study could have been assigned to any of the involved stakeholders. However, it is worth acknowledging their decision to outsource the project, and get the general picture of the risks of runway combination changes from an external and unbiased consultant (MovingDot).

[16] Risk analysis, *2.2. Risk analysis* in '2. Methodology', p. 13
[17] *9.4.6. Safety risk assessment and mitigation*, ICAO SMM, Fourth Edition, 2018, p. 9-17
[18] *1.4. Integrated Risk Management*, ICAO SMM, Fourth Edition, 2018, p. 1-7

3.2.3 Data gathering

The three stakeholders have contributed to the analysis with event data, statistics and interviews. The quality of data collected is considered sufficient to support the detection of hazards and assessment of safety risks. There is always the option of adding extra sources of information, but it is important to keep in mind whether it brings additional relevant elements that support the arguments of the analysis. For instance, Helios recommended to feed the assessment with Line Operations Safety Audits (LOSA) from additional airlines that operate in and out of Schiphol. The result was that *"airlines participating in the Chief Pilot's meeting* (input from foreign/non-home-based carriers) *at LVNL were asked via a survey about their LOSA data. Of eight respondents, three airlines confirmed to have a LOSA programme, but none of them identified any events due to runway changes"*[19].

The statistics provide an overview of numbers and duration/timings of runway changes for the period 2016-2017. These data is supported by runway (combination) change related events from the three parties. Together this information seems adequate to contextualise the tendency (how, when…) in which the runway changes take place, as well as the consequences (impact, events) they may cause or contribute to trigger. An important element that has been followed in this process is to correlate findings based on observations with information provided (interviews) by the representatives of the different operational stakeholders. These contributed, for instance, to apply more focus on the workload and crew error that can be caused by runway combination changes.

3.2.4 Hazard identification

The logical step after processing the data is to identify the hazards. We must agree at this point with the approach taken by MovingDot. They cover a broad scope of operations at Schiphol, including *airport*, *ATC* and *airlines*. It is precisely that what seems appropriate for this case. In a mere safety assessment for changes, the hazards are generally narrowed to a specific change to the functional system. However in this case, and besides not facing a change, we are speaking about three (main) stakeholders, whose functional systems might be affected by hazards generated by the runway combination changes. Although together, the hazards have been assigned to stakeholders, but they are all connected by the same root cause and potential undesirable outcomes[20].

	Hazard
FC_OB_1	Incorrect take-off performance setting or incorrect runway programmed
FC_OB_2*	Incorrect departure procedure (e.g. SID) flown
FC_IB_1	Incorrect landing performance setting (e.g. flaps or auto brake settings
FC_IB_2	Flight / approach profile error
FC_IB_3	Incorrect runway configuration in mind (late vacating of runway)
FC_IB_4*	Incorrect approach procedure (e.g. STAR or ILS) flown
FC_IB_5	Incorrect missed approach or go around procedure in mind
ATC_OB_1	Airport and operational complexity & workload
ATC_OB_2	Misunderstanding of runway status
ATC_IB_1	Airport and operational complexity & workload
ATC_IB_2	Misunderstanding of runway status
Airport-operations_1	Ground flows change
Airport-operations_2	Planning of and time for asset maintenance (runways, taxiways, systems, etc.)
Airport-operations_3	Timing and execution of runway checks incl. Birdcontrol

Figure 2. Flight crew, ATC and airport operations hazards with respect to runway (combination) changes[21]

[19] Risk analysis, *4.2.3.4. Airline LOSA data* in '4. Data and stakeholder-based findings', p. 28
[20] The *Risk analysis* also reiterates in several parts *"whereas a hazard might be categorized as FC or ATC, their causes and/or operational outcomes are intertwined and therefore a hazard might be applicable to both. As such, common aspects could potentially lead to undesirable outcomes if left unaddressed."*
[21] Risk analysis, *5.1. Identified hazards* in '5. Risk analysis', p. 31

The amount of hazards seem adequate to the scope of the assessment. Additional hazards could always be found, but they do not assure an assessment improvement. The point of hazard detection is to stress the most likely conditions with a potential damaging outcome, as seem to be reflected in the *Risk analysis* hazard detection.

3.2.5 Initial risk indication and risk matrix results

The risks of harmful effects introduced by the detected hazards were later analysed in a safety risk management workshop with stakeholder representatives. As aforementioned, a qualitative approach is fairly accepted. Risks are a combination of the probability/likelihood and severity of occurrence of a harmful effect. These have been well detailed in *Initial risk indications of safety impacts* (section 5.2. of the *Risk analysis*), providing the result of the risk levels. The results have been plotted in a specific position of the matrix by agreement of the representatives. In this way, differences in risk matrices of stakeholders are accounted for.

In other safety assessments (e.g. changes to functional system, at level of individual stakeholders), the severity and likelihood are usually given specific quantitative values. The combination of both is what provides a specific special plot in a risk matrix. The method followed in the *Risk analysis* was different: *"Each plot was positioned and sized* (in the matrix) *until common agreement was reached"*[22], but it gets the same outcome results. The risk is classified on the basis of estimated likelihood and severity.

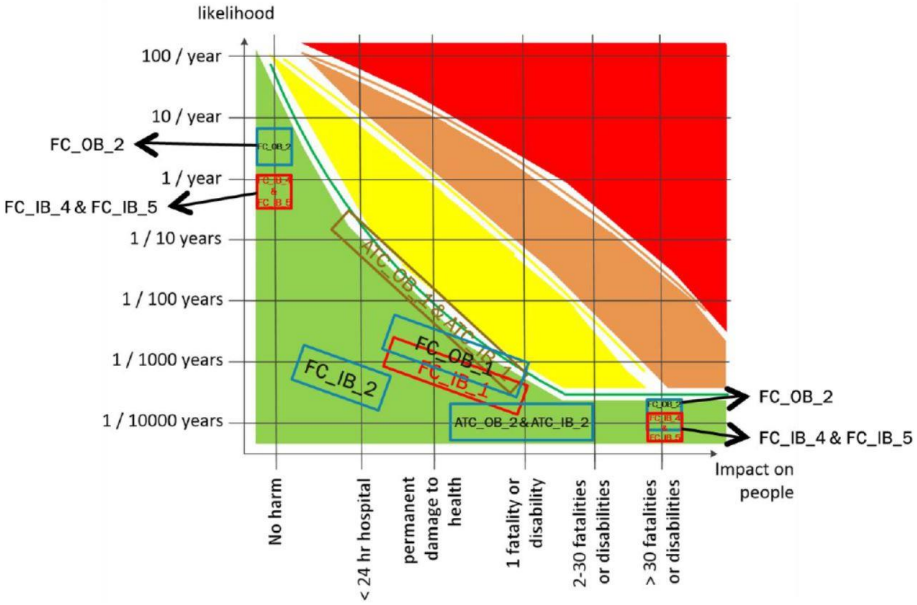

Figure 3. Plotting of commonly agreed risk classifications of the Flight Crew, ATC, and Airport Operations hazards and corresponding operational outcomes[22]

The report makes clear that the majority of detected risks are acceptable. Their hazards are plotted in the acceptable region of the matrix. The hazard "Airport and operational complexity and workload" is the only one between the 'acceptable' and 'tolerable' region. It carries the highest risks, but it is in an area that does not strictly need to be mitigated. The operational complexity at the airport and the present workload are tolerably safe. However, the scope of this risk, as well as the *Risk analysis* as a whole, are clearly sensitive subjects. It makes good sense that the decision of the TOP SAG was to mitigate not only the tolerable risk, but also to further assure acceptability of the rest of risks.

[22] Risk analysis, *5.2 Initial risk indications of safety impacts* in '5. Risk analysis', p. 33

3.2.6 Solutions to detected risks – The Risk reduction action plan (the *action plan*)

The *Risk reduction action plan* can be looked as the compendium of efforts that are being carried out to better improve the management of current and future safety risks. Interestingly, the majority of proposed measures are not directly aimed at reducing the risks related to runway combination changes. The *action plan* does not hide the fact that most of the mitigations are part of the "*performance improvement plan for reference period 3 (RP3, EU regulation No 390/2013) that LVNL provides to the Ministry"*[23]. The strategy is then to make use of planned improvements at Schiphol to increase safety levels and mitigate current and future safety risks as a whole. Thus, this is expected to help controlling the risks related with runway combination changes.

The discussion can always be open as to whether different or additional more specific measures could be considered. There is sometimes the misconception that extra risk reduction measures equals to safer operations, such as e.g. reducing the number of runway combination changes. In spite of that, the *Risk analysis* shows that, even though relevant, the number is not the main concern. In reality, the areas worth of attention are *"runway use stability, runway change (clearance) timing, and workload/human error"*[24]. According to the ISMS taskforce, better predictability of runway changes would help limiting the number of runway changes to those operationally necessary. Together with timely communication (with flight crew), these elements are expected to optimise human factors and provide a more stable traffic situation.

The proposed measures aim at tackling those areas *collectively*, which would reduce the risk of "airport and operational complexity and workload", as well as others. We do not disagree with that approach. The reasons given for runway changes are *weather*, *noise abatement regulations*, *runway conditions*, *availability of landing aids* and *capacity demand*[25]. It makes sense that the means to address the risks are diverse, and should include the joint forces and resources of involved (as well as impacted by the risks) stakeholders. Note that causes and/or operational outcomes of hazards for FC or ATC are intertwined. Individual measures may slightly improve the situation but they do not seem to provide a long term solution, moreover when expecting traffic growth[26]. The approach proposed by the taskforce is that the result of the mitigations on reducing the risks of runway changes depend on a collective effort to improve the predictability and stability of the operation.

The *action plan* has made a fair assessment of effectiveness of the risk reduction measures. The measures are expected to reduce the likelihood of hazards occurrence. Once again, this has been made qualitatively by means of expert judgement. We agree on the 'difficulty' that relies on trying to demonstrate the effectiveness of some strategic (long-term) solutions, which is also comparable to the analysis performed for the initial risk indication and plotting of results in the risk matrix. Therefore, it seems acceptable that the solutions are assessed qualitatively according to their expected outcomes. In this process, the effect of each measure has been individually assessed for every hazard. The results have been drawn in a table showing that all proposed solutions have either a positive (+) or neutral (o) effect (Figure 4).

According to these conclusions, the risk matrix was updated (Figure 5) in the *Risk analysis* to show that *"none of the mitigations is expected to increase the risk of the identified hazards"*[27]. On the contrary, the resulting matrix shows that measures currently being implemented are shifting the risk

[23] Risk analysis, *K.5. Mitigations, K.6. Conclusions and recommendations* in 'Annex K. Risk reduction action plan', p. 103, 115 & Action plan, *4. Mitigations, 5. Conclusions and recommendations,* p. 20, 34
[24] Risk analysis, '6. Conclusions', p. 39 & Risk analysis, *K.3. Background* in 'Annex K. Risk reduction action plan', p. 90 & Action plan, '2. Background', p. 6
[25] Risk analysis, '3. Runway usage', p. 14 & Risk analysis, *A.1. Runway (combination) usability criteria, A.2. Runway changes factors* in 'Annex A. Runway usage at Schiphol airport', p. 44 ,45
[26] e.g. unlike in the past, LVNL is nowadays responsible for all runway crossings or runway entries, irrespective of runway status. In the past, AAS' APC was responsible for runway crossings of non-active runways. *"It has proven an effective mitigation for preventing tows entering an active runway"*. Such solutions are limited in extent, and do not provide a long term reduction of risk of runway changes.
[27] Risk analysis, *5.4. Risk re-classification* in '5. Risk analysis', p. 36

"airport and operational complexity and workload" towards the 'acceptable' region, as well as further improving acceptability of other drawn risks in the matrix.

Code	Hazard	1. Continued development of AMAN	2. Continued development of CDM	3. Implementation of APOC	4. No re-clearances within TMA	5. Deployment of a second departure runway during day time	6. Optimizing the weather forecast data	7. Capacity Management	8. Traffic Distribution Page	9. Digitalization of Tower (Tower 2.0)	10. Increased capacity of airport infrastructure	11. Programs aimed at increasing joint awareness
FC_OB_1	Incorrect take-off performance setting or incorrect runway programmed	o	+	o/+	o	++	o/+	o/+	o	o	o	o/+
FC_OB_2	Incorrect departure procedure (e.g. SID) flown	o	+	o/+	o	++	o/+	o/+	o	o	o	o/+
FC_IB_1	Incorrect landing performance setting (e.g. flaps or auto brake settings	o/+	o	o	++	o	o/+	o/+	o	o	o	o/+

Figure 4. Example of the expected effectiveness mitigating measures on three hazards[28]

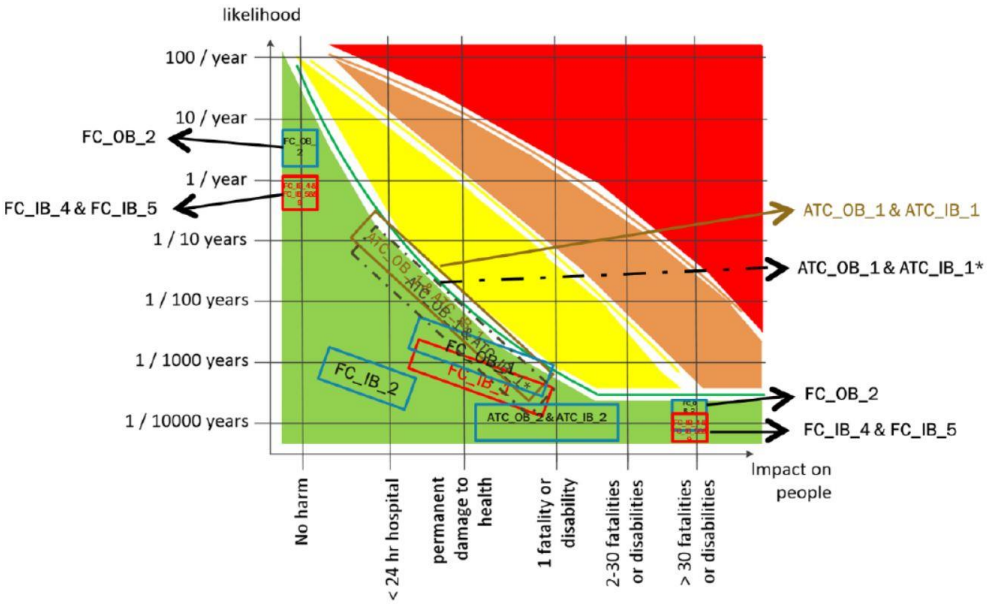

Figure 5. Plotting of ATC_OB_1 & ATC_IB_1 risk classification taking into account the measures being implemented[29]

The assessment of measures is made having account of the positive effect of the initiatives in the LVNL performance improvement plan. The *Risk analysis* claims that *"various already implemented system and procedural changes* have *a positive safety impact on several of the identified hazards"*[30], *"Recent implemented risk reduction actions have contributed to increased ATC stability"*[31]. The results of the assessment of measures are therefore based on the assumption that current and future improvements are going to have a direct positive effect on the overall risk reduction of runway combination changes.

The traffic growth is considered in the *action plan*, but as previously mentioned (section 3.1.3), it is based on a descriptive analysis of statistical data. The data is showing a decrease in runway combination changes and late runway changes given to pilots. We understand that a complete assurance of a positive effect cannot be provided in the *Risk analysis.* Hence, a continuous

[28] Risk analysis, *K.5. Mitigations* in 'Annex K. Risk reduction action plan', p. 114 & Action plan, *4. Mitigations*, p. 32
[29] Risk analysis, *5.4. Risk re-classification* in '5. Risk analysis', p. 37
[30] Risk analysis, *5.5. Resilience* in '5. Risk analysis', p. 38
[31] Risk analysis, *6.1. Runway use stability* in '6. Conclusions', p. 40

monitoring is going to be performed at level of both ISMS[32] and operational stakeholders[33] to detect potential negative effects and risks during and after the implementation of the measures. By these means the current risks remain controlled, and new actions would be taken if risks emerged in the future.

The implementation of the measures might be subject to shortcomings or drawbacks. It is convenient not to forget that they depend on availability of stakeholders resources, and it is unpredictable at what point they are to be fully deployed. *Costs*, *feasibility*, *support*, *enforceability, sustainability* and *side effects* are not part of the report. Many of the measures are strategic improvements, and it is to assume that elements like *costs* or *side effects* have been considerably analysed by the responsible stakeholder for their implementation. The fact that 8 out of the 11 measures are being currently implemented[34] proves their *feasibility*. The monitoring tasks take account of the effectiveness of the measures and risks throughout their implementation.

In the same way, safety assessments for changes to functional systems are also a means of assurance. These make sure of controlling the safety risks arising from changes at stakeholder level. Besides, safety is also *"analysed in its entirety by the sector parties in the event of major changes"*[10]. So far the *Risk analysis* claims that *"there are no significant know changes that might have an impact on the outcomes of the risk analysis"*[6]. In addition, this is supported by the fact that *"per regulatory restrictions, no significant traffic growth is foreseen for Schiphol in the foreseeable future"*. We agree that a sudden situational change is unlikely in the future. The management of safety risks within a context of progressive and expected traffic growth is sufficiently covered by current monitoring activities, at stakeholder and ISMS level.

We acknowledge that the risks detected in the Risk analysis are acceptable (and only one tolerable), that stakeholders are committed to implement the measures to further reduce the risks and that effectiveness of measures and risk control is assured by means of monitoring. Nevertheless, and it is not a must, the effect of some measures could be further analysed to provide assurance and predictability by means of a *Fast-Time Simulation (FTS)*. In a predictive analysis *"some systems allow users to model different scenarios of risks or opportunities with different outcomes"*[7]. The FTS can build up a scenario with the feasible proposed measures for a simulation and provide the complete future operational complexity at Schiphol. A future scenario of increased planning and improved systems/infrastructures could in return provide assurance of reduction of runway combination changes. The solutions that could be feasibly modelled are: *1. Continued development of AMAN, 2. Continued development of CDM*, *5. Deployment of a second departure runway during daytime* and *10. Increased capacity of airport infrastructure*.

A FTS could be built in three scenarios:

1. *Current scenario*: model an average day in the current operational context.
2. *Current scenario with expected traffic growth*: check complexity and effects of an increase in traffic in current scenario.
3. *Future scenario with implemented measures and expected traffic growth*: assurance of effectiveness of proposed measures and verification of a reduction in complexity.

A simulation would be an add-on to provide predictability to the *Risk analysis* and assurance of effectiveness of the selected measures regarding a reduction of the airport complexity, as well as a potential use reduction of runway combination changes. This is just a tool for drawing the expected outcome of the measures. In any case, the safety risks will keep being controlled by the aforementioned means of monitoring at level of stakeholders and ISMS.

[32] As part of the Covenant, the ISMS assumes responsibility to provide assurance of the measures derived from safety risks that affect several sector parties operating at Schiphol.
[33] e.g. *"Use of a second departure runway is actively monitored by LVNL, with potential impacts being evaluated and documented"*[30] (runway combination changes trends); relevant reported events
[34] Risk analysis, *5.4. Risk re-classification* in '5. Risk analysis', p. 36

4 THE FOURTH RUNWAY RULE

4.1 REQUIREMENTS FOR NOISE ABATEMENT WITHIN CURRENT SCHIPHOL COMPLEXITY AND RISK ANALYSIS

The NNHS intends to resolve *"the unintended side effects of the current system of enforcement points which caused more noise impact"*[35]. New rules have been designed that dictate the preferred runway use, so air traffic management now always takes place in the most noise preferential way. In this context, the block system followed at Schiphol makes sometimes necessary the use of a fourth runway on a temporary basis to ensure a smooth transition between outbound and inbound peaks. The 4th runway rule of the NNHS sets a *"maximum for the number of aircraft movements that will be handled on the fourth runway in one day and over the course of a year, during periods that two take-off runways and two landing runways are simultaneously in use"*[36].

The standard for such use came from a petition of some parties (particularly the residents delegation) collaborating in the negotiations of the 2008 Alders Agreement. According to the residents' delegation, this was intended to guarantee the rest periods of the surrounding residents[37]. Contrarily, the LVNL report states that the 4th runway rule *"does not necessarily contribute to a reduction in the total number of noise-affected dwellings, people severely annoyed and people who are severely sleep-disturbed"*[38].

Within the *Risk analysis of runway combination changes*, the 4th runway rule, as well as the other rules, are just a parameter that was taken into consideration to analyse the current complexity of operations. The *noise abatement regulations* (as referred in the *Risk analysis*) are part of other given reasons for runway changes, being a source that potentially leads to the hazards. As afore-mentioned, ATCOs are nowadays used to runway changes procedures. However, the interviews held with operational stakeholders underlined that there is *"the perception that with the growth of Schiphol these political agreements increasingly restrict the efficiency of Schiphol. At times it is perceived that not the most optimal runways (wind-wise) are activated due to noise restrictions"*[39]. Whereas this might be the perception from stakeholders, there are studies (specify) that reflect the efficiency of the NNHS in contraposition to a system based on the used of 4 simultaneous runways: 2 inbound and 2 outbound.

4.2 SHORT AND MID-TERM MEASURES TO REDUCE THE USE OF THE 4TH RUNWAY

The aviation sector at Schiphol is aware that, in the current situation, the 4th runway rule will lead to *"technical and operational bottlenecks, as well as political and administrative discussions"*[40] in case no supplementary measures are applied. In the meeting at Schiphol it was clear that an increase in traffic in the current scenario may require a further use of the fourth runway. However, the sector parties evidence their intentions to accommodate the demands of the NNHS. The report from LVNL address (possible) measures to reduce the use of the fourth runway. These could be called mid-term and short-term measures.

The mid-term would be those needing longer collective efforts of Schiphol parties. The majority of these measures concern changes to the functional system, which require a longer implementation process, including an assessment of safety risks (safety assessment, section 3.2.2):

[35] *3.4. The new standards and enforcement system (NNHS)*, The fourth runway rule and the Schiphol operations, LVNL, Version 1.0, 19 July 2019, p. 17
[36] [Foot. 35], p. 18
[37] *3.5. The fourth runway rule*, The fourth runway rule and the Schiphol operations, LVNL, Version 1.0, 19 July 2019, p. 18
[38] *3.6. Summary*, The fourth runway rule and the Schiphol operations, LVNL, Version 1.0, 19 July 2019, p. 23
[39] Risk analysis, *4.1. Operational stakeholder identified issues with regards to RWY changes* in '4. Data and stakeholder-based findings', p. 16
[40] *4. Measures to reduce use of the fourth runway*, The fourth runway rule and the Schiphol operations, LVNL, Version 1.0, 19 July 2019, p. 25

- *Measure A: increasing (peak) hourly capacity*
- *Measure B: more efficient use of existing capacity*
- *Measure C: forcing 2+1 runway use by imposing strict regulations*
- *Measure D: delaying inbound traffic by means of holding*[41]

These solutions do not generate a safety impact for the time being. They would be the result of ongoing/future projects at Schiphol. In fact, some of the initiatives to deploy these measures are shared with those from the previously mentioned performance improvement plan (section 3.2.6), e.g. capacity management, A-CDM, AMAN. We cannot but agree with LVNL concerning the effectiveness or feasibility of the proposed solutions. Measures A and B aim for increasing peak hourly capacity and more efficient use of existing capacity. As discussed in the meeting at Schiphol, a configuration of 2+1 runways without dependence of a fourth one is only possible if operations take place 100% according to planning or is sufficient slack (firebreaks) are incorporated in the planning. This also includes a responsibility on the part of the stakeholders to operate more according to plan. The collection of projects that attempt to increase capacities, predictability and planning are expected to allow reducing dependency on the fourth runway. Measures C and D should be avoided from a network quality standpoint, but are still necessary.

The short-term measures are the set of measures that have been applied from the beginning of summer 2019. They are not independent new measures. Instead, they either apply or are contributors to the previous ones:

- *Set of measures section 1: systematic improvement of On Time Performance (OTP)*. Contributes to measure B
- *Set of measures section 2: imposing operational control measure for runway use*. Expression of measure C.
- *Set of measures section 3: trial flights according to Target Time Over (TTO)*. Contributes to measure B.
- *Set of measures section 4: reducing the Runway Occupancy Time (ROT)*. Contributes (as an enabler) to measure A.[42]

Unlike mid-term measures, these ones do not imply a change to the functional system. As stated in LVNL report and reconfirmed during the meeting at Schiphol, the measures implemented last summer *"use current and existing methods, techniques and ways of working"*[43]. In this kind of scenarios we generally agree that implementation does not need to be preceded by an exhaustive evaluation of safety impacts. The safety paragraphs of each measure in the report declare absence of safety effects and conformity with safety standards. It seems also that there is a monitoring of these measures to avoid future impacts on safety risks. For instance, within the *control measures for runway use*, the report mentions that the number of late runway changes are going to be monitored. 'Increase of late runway changes' or 'workload for the ATCO' would be risks derived from the measure. LVNL claims to keep track of these measures are part of their SMS monitoring activities (KPIs/trends, occurrence reporting).

4.3 MANAGEMENT OF SAFETY RISKS DERIVED FROM THE MEASURES

Besides the short-term measures in place since summer 2019, the mid-term measures are also expected to be implemented to further reduce the use of the fourth runway. Unlike short-term measures, mid-term measures require changes to the functional system. LVNL will have to perform the proper safety assessments whenever the new changes are planned. As aforementioned, operational stakeholders are required to carry out safety assessments for changes as per ICAO (international) standards and European regulations. This implies that safety risks from mid-term

[41] [Foot. 40], p. 25-34
[42] *5. Set of measures for summer 2019*, The fourth runway rule and the Schiphol operations, LVNL, Version 1.0, 19 July 2019, p. 35-42
[43] [Foot. 42], p. 35

measures are going to be managed and controlled by LVNL (or other stakeholders, if impacted) from the moment they are to be implemented within their specific functional system.

There is also a global view at ISMS level of how new improvements/changes impact the overall risks at Schiphol. If changes derived from mid-term measures had an impact at global Schiphol level, these would be analysed by the sector parties[10]. We cannot either forget that the ISMS monitors the safety risks that affect several sector parties and evaluates the effectiveness of measures taken[11] (section 3.1.3). Hence, management and control of safety risks derived from the mid-term measures are assured at stakeholder and ISMS level, by means of both the safety risk assessment of changes and the subsequent monitoring activities. Once implemented, the measures will be tracked by both entities and, if required, updated. We agree that, by these means, safety risks are consequently controlled.

It is important to reiterate that short-term measures are not and will not be a safety concern as long as they do not imply a change to the LVNL functional system and they keep using current methods, techniques and ways of working. These measures are being currently monitored to track trends and effectiveness.

The majority of mitigation measures defined in the *action plan* do not have an impact on the solutions to reduce the use of the fourth runway. Only two measures are overlapped: the "deployment of the second runway during day time" (in *Risk analysis*) and "imposing control measures for runway use" (in *Fourth runway rule*). On top of deploying a second runway during daytime, there is currently an operational control measure that puts a limit to the use of the fourth runway from 15:30h. These two measures are actually complementary. According to discussion in the meeting, setting a limit to the use of the fourth runway after 15:30h is expected to reduce complexity of operations, as well as the psychological pressure and workload of the ATCO. It is recommendable to track the effectiveness of these two measures. Besides regular monitoring[44], it would also be recommendable to make a specific review or survey within a year time on the specific impact of concentrating 4th runway operations up to 15:30h.

[44] *"Use of a second departure runway is actively monitored by LVNL, with potential impacts being evaluated and documented"*; Risk analysis, *5.5. Resilience* in '5. Risk analysis', p. 38

5 CONCLUSION AND RECOMMENDATIONS

After having reviewed the safety achievements reached so far by the ISMS, we acknowledge the taken steps to foster safety of operations at Schiphol airport. Bringing the key stakeholders (ATC, airport, airlines, ground handlers, refuelling services) to the table in one body is a decisive step towards ensuring the future viability of airport safety.

In our view, the *Risk analysis* sets a course towards evaluating future challenges. The main one being to cope acceptable risk levels with future traffic growth, network quality and noise abatement regulations.

As part of their business development, the sector evidences to be working on improvements that reduce the assessed risks of runway changes. The activities and methodology followed in the ***Risk analysis*** are adequate to the scope of the subject. The three key stakeholders have contributed to provide and contrast data, but also to agree on the level of risk of the detected hazards.

The measures described in the ***action plan*** are capable to address the concerns regarding the runway combination changes. Most of them are part of the LVNL performance improvement plan. They are not mere mitigations, but rather pending improvements at the airport, the implementation of which encompasses the risks of operational complexity, as well as other detected risks, from its root. The majority of measures are already in process of implementation and some system and procedural changes have proven a positive safety impact on reducing the risk. The effect of these solutions has been assessed by the sector at ISMS level and it is estimated to reduce the risk of several hazards (in the risk matrix), including the risk of operational complexity and workload.

- The **effectiveness of measures** in the *action plan* and the **control of safety risks** of runway combination changes are assured by both the ISMS and the SMS of operational stakeholders. This is done via continuous monitoring (KPIs/trends, occurrence reporting), change management processes and the safety check prior to the declared capacity for slot allocation at Schiphol. These processes guarantee that risks are identified and mitigated before the increase in air traffic. The Ministry should oversee these safety assurance activities.

Within the *Risk analysis*, the fourth runway rule is just part of the noise abatement regulations, which are a parameter taken into account during the assessment of safety risks. The LVNL report ***Fourth runway rule*** reflects the service provider commitment to accommodate the needs of the NNHS and to further reduce the use of the fourth runway. It has become evident that the measures implemented on summer 2019 did not imply safety risks, as they made use of techniques, methods and ways of working in place at LVNL. On the contrary, mid-term measures involve carrying out changes to the LVNL functional system. According to standards and European regulations, the safety risks will have to be assessed and, if required, mitigated in a safety assessment for changes.

- Similarly to the action plan, the **effectiveness of measures** and **control of safety risks** from the *Fourth runway rule* are assured by means of continuous monitoring and the change management processes. The short-term measures are currently being monitored by LVNL (e.g. workload to the ATCO, deviations in trends). The mid-term measures will be first subject to a safety assessment for changes, and also monitored once implemented.

5.1 ANSWERS TO THE INQUIRIES FROM THE MINISTRY

5.1.1 Runway combination changes

- **Has the analysis been performed in a good, solid manner in accordance with the applicable (international) methodologies?**

[Section 3.2.1] The analysis has been performed according to the main steps of a Safety Risk Management process as per ICAO SMS. The ISMS does not behave as an individual stakeholder with an SMS, but the analysis has suitably followed the same steps: "*hazards identification*, *safety risk assessment*, *safety risk mitigation* and *risk acceptance"*[15]*.*

- **Have all relevant stakeholders with an SMS been interviewed and have they properly been involved in the analysis?**

[Section 3.1.5] The *Risk analysis* is the result of a joint effort of the three key operational stakeholders at Schiphol: ATC, airport and airlines. They are part of the ISMS, a fact that has facilitated collaboration. The *Risk analysis* shows data inputs from the three stakeholders: data collected (runway changes frequency/timing, event data) and interviews (first with stakeholders' representatives, and later a meeting was held with Chief pilots of airlines). The common risk matrix used in the analysis is the result of a joint decision-making process at ISMS level. The findings, results and arguments from data gathered were commonly agreed by the three collaborating parts.

- **Have all concerns, points of attention and recommendations from the Dutch Safety Board regarding the safety impact of runway combination changes been properly included in the analysis of MovingDot and the subsequent review by Helios?**

[Section 3.1] The final version of the *Risk analysis* and *action plan* address through their respective reports the OVV concerns regarding *operational complexity* at Schiphol, which is in fact the detected risk between the 'acceptable' and 'tolerable' region in the risk matrix; *increase in number of events since 2014*; the *future levels of safety in a context of traffic growth*; and the *human factor concerns related to high workload/pressure and complex, dynamic operations*. The *Risk analysis* was modified after the review by Helios. The analysis, for instance, extended the data sources and took account of future traffic growth in the *action plan*.

- **Are additions to the analysis required in this context?**

[Section 3.1.3 & 3.2.6] The *Risk analysis* and *action plan* provide all required information as per the methodology described. There is only one aspect that could be suitably enlarged: to provide a further predictive analysis regarding the effectiveness of defined solutions within a context of traffic growth. The future trends of runway changes are based on the expectation that past data is going to keep the same tendency (e.g. reduction of the percentage of Schiphol outbound flights with a runway change). This is a fair approach having consideration that trends and effectiveness of measures are going to be actively monitored, and safety risks controlled. However, a predictive exercise could supplement the current analysis.

Recommendation: Perform a FTS of the current and future *operational complexity* at Schiphol. There are mainly four measures that could be feasible modelled. The FTS scenarios could assist in providing assurance of the expected effectiveness of measures, as well as of a reduction of runway combination changes.

- **Is it ensured that the risks remain controlled, also when there is growth in air traffic?**

[Section 3.2.6] The effectiveness of the defined solutions in the *action plan* is going to be monitored from the moment of their implementation. A continuous monitoring (KPIs/trends, occurrence reporting) is going to be performed at level of both the ISMS and operational stakeholders to detect potential negatives effects and risks. By these means the current risks remain controlled, and new actions would be taken if risks emerged in the future.

Additionally, both the ISMS and stakeholders (within their SMS) carry out management of changes: either major changes affecting different sector parties or changes to the stakeholder functional system, respectively. This implies making an assessment of the safety risks and taking required measures, if necessary. On a daily basis, risks are managed by a safety check prior to the declared

capacity for slot allocation. These processes guarantee that risks are identified and mitigated before an increase in air traffic.

Recommendation: It is a good monitoring practice and safety assurance to keep a risk assessment up to date. This is a common practice at DFS, even if the risk are found acceptable. It is therefore recommended to make a periodic review of the *Risk analysis* (e.g. in 3-4 years) time to update data, check effectiveness of the measures and validate the reduction of risks.

- **Are the identified risks sufficiently and adequately covered by the proposed measures and solutions in the risk reduction action plan?**

[Section 3.2.6] Indeed, the proposed measures have been confirmed to reduce the identified risks. The Risk analysis has detected three areas worth of attention that contribute to the risks: *"runway use stability, runway change (clearance) timing, and workload/human error"*[24]. The measures aim at tackling these areas collectively. They are expected to increase the predictability of a runway change, which would help limiting the number of runway combination changes to those operationally necessary. The expected effectiveness of these measures has been assessed at ISMS level, and they were found to reduce the risk of "operational complexity and workload" to the 'acceptable' region of the matrix, as well as further reduce other (already acceptable) detected risks.

- **Have the solutions been properly mapped in terms of effectiveness, costs / benefits, feasibility, support, enforceability, sustainability and side effects?**

[Section 3.2.6] The measures have been mainly mapped in terms of effectiveness and benefits. *Costs*, *feasibility*, *support*, *enforceability, sustainability* and *side effects* are not part of the report. Many of the measures are strategic improvements. Therefore, it is to assume that elements like *costs* or *side effects* have been considerably analysed by the responsible stakeholder for their implementation. The fact that 8 out of the 11 measures are being currently implemented proves their *feasibility*.

- **Are other measures and solutions conceivable within the current operational concept that could reduce the identified risks?**

[Section 3.2.6] No additional measures are envisaged within the current operational concept. There is sometimes the misconception that extra risk reduction measures equals to safer operations, such as e.g. reducing the number of runway combination changes. In spite of that, the *Risk analysis* shows that, even though relevant, the number is not the main concern. Besides specific solutions (e.g. deployment of a second departure runway during daytime), many of the defined measures are part of a strategic improvement plan. These measures are going to contribute improving the identified areas worth of attention: *"runway use stability, runway change (clearance) timing, and workload/human error"* [24].

5.1.2 Fourth runway rule

- **What measures are necessary according to the ISMS parties to comply with the 'fourth runway rule'?**

[Section 4.2] LVNL has defined two sets of measures to reduce the use of the fourth runway. The first are ***mid-term measures***: *"A. increasing (peak) hourly capacity; B. more efficient use of existing capacity; C. forcing 2+1 runway use by imposing strict regulations; and D. delaying inbound traffic by means of holding"*[41]. The second are ***short-term measures***: *"1. Systematic improvement of On Time Performance (OTP); 2. Imposing operational control measure for runway use; 3. Trial flights according to Target Time Over (TTO); and 4. Reducing the Runway Occupancy Time (ROT)"*[42]. Short-term measures are in place since summer 2019 and they are contributors to future mid-term measures.

- **Have the safety risks of these measures been adequately identified?**

[Section 4.2] The measures in the *Fourth runway rule* report are defined within the organisational envelope of LVNL. The safety risks of the foreseen measures do not have to be specifically identified in the report, as they are managed within their SMS.

We agree that the short-term measures are not a trigger for safety risks, because they *"use current and existing methods, techniques and ways of working"*[43]*.* For instance, setting a limitation of use of the fourth runway until a certain time (15:30h) does not require changes; it makes use of current methods and ways of working to adapt to the measure needs. Nevertheless, the report has included safety paragraphs for each measure to declare absence of safety effects and conformity with safety standards.

On the other side, the mid-term measures require to perform changes to the functional system. The changes triggered by these measures will be subject to safety assessments for changes according to international standards (ICAO) and European regulation. Within this process, safety risks are identified and assessed.

- **Are there going to be additional measures implemented to manage these risks?**

[Section 4.2] Again, the short-term measures do not foresee any (additional) measure, because they are not a source of safety risks. Contrarily, the mid-term measures may require, if necessary, to define and implement mitigating measures in the scope of the safety assessment and change management process.

5.1.3 Interdependence

- **Has an adequate assessment been made as to whether the measures related to compliance with the 'fourth runway rule' have a potential (negative) effect on the risks associated with runway combination changes and vice versa?**

Such assessment has not been made. However, it is implicit in the nature of the LVNL measures that part their purpose is going to contribute reducing the risks of runway combination changes. The measures intend to increase and make a more efficient use of existing capacity, allowing to depend less on the fourth runway, thus potentially reducing operational complexity.

- **Have additional measures been taken to manage these risks?**

[Section 4.3] No additional measures are required. The aim of the measures related to the *Risk analysis* is to reduce the risks of runway combination changes. The three key operational stakeholders contribute to their implementation. On the other side, the LVNL measures aim at reducing the use of the fourth runway. The measures in both reports can be considered complementary, according to the expected positive effect of LVNL measures on the use and increase of existing capacity. What could be potentially measured is the effect of an overlap of solutions by the same stakeholder. At this moment LVNL apply "deployment of the second runway during day time" (in *Risk analysis*) and "imposing control measures for runway use" (in *Fourth runway rule*). The use nowadays of the fourth runway has been limited during daytime until 15:30h.

Recommendation: Track the effectiveness of the two measures. Besides regular monitoring[44], it is recommendable to make a specific review or survey in a year time on the specific impact of concentrating 4th runway operations up to 15:30h.