Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Zivilluftfahrt BAZL

Anhang A.4

Flughafen Zürich
Sachplan Infrastruktur der Luftfahrt (SIL)

Assessment of third party risk around Zürich airport

vom 17. Juni 2016

COMPANY CONFIDENTIAL

Assessment of third party risk around Zürich Airport

In the context of SIL process Zürich Airport

Customer

FOCA Switzerland

NLR-CR-2014-215 - July 2014

__NLR__ – Dedicated to innovation in aerospace

National Aerospace Laboratory NLR
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands
Tel +31 (0)88 511 3113
www.nlr.nl

Assessment of third party risk around Zürich Airport

In the context of SIL process Zürich Airport

Y.S. Cheung and L. de Haij

Customer

FOCA Switzerland

July 2014

Customer	FOCA Switzerland
Contract number	790000305 (NLR-project 2494117)
Owner	FOCA Switzerland
Division NLR	Air Transport
Distribution	Limited
Classification of title	Company Confidential
Date	July 2014

Approved by:

Author Y.S. Cheung L. de Haij	Reviewer R. de Jong	Managing department R. Hermans i.a.
Date 24/7/14	Date 24/7/14	Date 24/7/14

Summary

The Federal Office of Civil Aviation (FOCA) of Switzerland and Flughafen Zürich AG are jointly working on the realisation of the “Sachplan Infrastruktur der Luftfahrt” (SIL), the Sectoral Aviation Infrastructure Plan, for Zürich airport. In the SIL Zürich a number of operational variants with different use of runways and flight routes are considered. Nine operational variants are studied in detail in the process of SIL Zürich. These variants concern changes in the airport operation due to development foreseen in the future to cope with the expected growth of the air traffic at Zürich airport.

National Aerospace Laboratory NLR is contracted by FOCA to conduct a study on third party risk, i.e. the risk for people in the vicinity of Zürich airport, for the SIL variants 1 through 4, 5a, 5b, 5c, 6 and 7. FOCA requires that the information on third party risk should be made available in support of the decision-making. The information helps evaluate how each SIL-variant performs in terms of risk, and helps assess whether the risk around Zürich airport is of the same order of magnitude when compared to other Western,international airports.

The risk assessment comprises two parts. The first part encompasses the calculations of the individual risk and the societal risk of all nine SIL Zürich variants mentioned before, and the visualisation of the results: individual risk contours and societal risk curves (also known as *FN*-curves). The second part involves the mutual comparison of the risk of the variants and the overall comparison of Zürich airport’s risk with other studies on third party risk around an airport.

The results of the individual risk show that the 10^{-6}/year contours cover part of the built-up and residential areas in the surroundings of the airport. The risk contours do not form easy-to-grasp risk information for comparing variants. This is because on one hand a few variants have a quite comparable traffic situation as that of variant 1 which is chosen as basis for comparison, and on the other hand the levels of risk contour that are chosen in this study are limited to 10^{-5}/year and 10^{-6}/year only. Therefore the differences in the risk contours may not be significant.

The results of the societal risk show that the societal risk curves or *FN*-curves of the SIL Zürich variants lie in a narrow band and they do not deviate much from each other. However, by investigating the societal risk in detail, it is found that variant 2 has the highest risk for the group sizes considered. Variant 7 is the only variant that has smaller risk when compared with variant 1. All other variants have either identical risk to or higher risk than variant 1. Moreover, when

compared with other western international airports, the societal risk curve of Zürich airport shows a comparable pattern and is not exceptional.

Content

Abbreviations

Acronym	Description
A/C	Aircraft
DTHR	Displaced threshold (landing)
IR	Individual Risk
km	Kilometre(s)
m	Metre(s)
MTOW	Maximum Take Off Weight
NLR	National Aerospace Laboratory NLR
RWY	Runway
SIL	Sachplan Infrastruktur der Luftfahrt (Sectoral Aviation Infrastructure Plan)
sq.	square
SR	Societal Risk
WTC	Wake Turbulence Category
yr	year

Definitions

Definition	Description
Aircraft accident (third party)	Any unintended contact with the ground outside the runway. This includes all types of occurrences including for instance fatal accidents, non-fatal accidents, major losses and hull losses.
Aircraft movement	A take-off or a landing (equivalent: a departure or an arrival)
Calculation grid	A small square area for which risk value is calculated
ICAO code	ICAO Aircraft Type Designator (Doc 8643). Aircraft type is (mostly) denoted by a combination of four letters and numbers.
Overrun	An accident in which the aircraft runs off the end of the runway.
Overshoot	An accident in which the aircraft contacts the ground beyond the end of the runway.
Straight-in	A straight landing flight route or approach path to the runway.
Study area	A defined part of the geographical area outside the perimeter of the airport, which is considered to be subject to increased risk of aircraft accidents due to the presence of the airport.
Third party	Inhabitant around an airport
Undershoot	An accident in which the aircraft contacts the ground before the runway while on (final) approach.
Veer-off	An accident in which the aircraft runs off either side of the runway.

1 Introduction

The Federal Office of Civil Aviation (FOCA) of Switzerland and Flughafen Zürich AG are jointly working on the realisation of the “Sachplan Infrastruktur der Luftfahrt” (SIL), the Sectoral Aviation Infrastructure Plan, for Zürich airport. As described by the airport, the SIL sets out the purpose, required perimeter, the main aspects of use, and development and general operating conditions for the airport.

In the SIL Zürich a number of operational variants with different use of runways and flight routes are considered. Nine operational variants are studied in detail in the process of SIL Zürich. The original description of the SIL Zürich variants in German is given in this report on the next page. These variants concern changes in the airport operation due to development foreseen in the future to cope with the expected growth of the air traffic at Zürich airport. The time frame for this development situation is around 2030.

Third party risk, i.e. the risk for people in the vicinity of an airport, is among other aspects like capacity, economics and environmental impacts, an aspect that should be addressed in the context of the SIL-process for Zürich airport. FOCA requires that the information on third party risk should be made available in support of the decision-making. The information helps evaluate how each SIL-variant performs in terms of risk, and helps assess whether the risk around Zürich airport is of the same order of magnitude when this is compared with other western international airports.

National Aerospace Laboratory NLR is contracted by FOCA to conduct a study on third party risk around Zürich airport for the SIL variants mentioned. In the risk assessment, both individual risk and societal risk are determined. The risk assessment comprises two parts. The first part encompasses the calculations of the individual risk and the societal risk of all nine SIL Zürich variants, and the visualisation of the results: individual risk contours and societal risk curves (also known as *FN*-curves). The second part involves the mutual comparison of the risk of the variants and the overall comparison of Zürich airport’s risk with other studies on third party risk around an airport. The emphasis of the comparison is on the societal risk.

Variante 1: Verspätungsabbau
Die Variante 1 basiert auf den Festlegungen und Vororientierungen der 1. Etappe des SIL-Objektblatts mit folgenden Abweichungen gegenüber dem Status Quo:

- Infrastrukturseitig werden Schnellabrollwege, eine Umrollung der Piste 28 im Osten sowie die Verlängerung der Pisten 28 und 32 berücksichtigt.
- Zusätzlich sind (in sehr geringem Umfang) Abflüge nach Süden geradeaus bei Bise oder Nebel zum Verspätungsabbau vorgesehen.

Variante 2: Kreuzungsfrei
Alle Abflüge erfolgen beim Nordkonzept nach Süden geradeaus. Die Piste 28 wird beim Nordkonzept nicht genutzt, weshalb diese Variante eine max. Anzahl von Südabflügen geradeaus aufweist.

Variante 3: Bise oder Nebel ohne Start 16 left
Zusätzlich zum Betrieb gemäss Variante 1 finden Südabflüge geradeaus bei Bise oder Nebel immer und nicht nur bei Verspätung Verwendung. Hauptstartpiste ist die Piste 28.

Variante 4: Bise oder Nebel ohne Start 16 left und 10
Zusätzlich zum Betrieb gemäss Variante 3 wird bei Bise die Piste 10 geschlossen, um Kreuzungspunkte am Boden und in der Luft zu eliminieren. Bei Bise erfolgen somit alle Abflüge nach Süden geradeaus.

Variante 5a: Start 16 straight in der Mittagswelle ohne short right
Zusätzlich zu Variante 4 wird nicht nur bei Nebel oder Bise, sondern auch in der Spitzenzeit am Mittag (10.00 bis 14.00 Uhr) nach Süden geradeaus gestartet.

Variante 5b: Start 16 straight only in der Mittagswelle
Eliminierung gekreuzter Startpisten in der Mittagsspitze. Damit werden während der Spitzenzeit am Mittag alle Starts geradeaus nach Süden geführt.

Variante 5c: Start 16 straight in der Mittagswelle mit short right
Wie die Variante 5a, jedoch unter Verwendung des „short right“. Damit werden während der Spitzenzeit am Mittag rund 90% der Starts auf der Piste 16 mit einer frühen Rechtskurve abgewickelt.

Variante 6: Start 16 straight generell ohne short right
Die Piste 28 trägt die überwiegende Zahl der Abflüge. Alle Starts 16 werden wie bei der Variante 2 geradeaus (straight) geführt.

Variante 7: Optimierung Verhältnis Safety / Starts 16 straight
Während der Mittagsstartwelle wird das Ostkonzept eingesetzt. Der Südabflug geradeaus wird bei Bise verwendet.

This report documents the third party risk assessment for all nine SIL Zürich variants. After this introduction, section 2 addresses the methodology adopted in the analysis and briefly describes the data applied in the risk assessment. Section 3 presents the results of the calculations of both individual risk and societal risk. Comparisons of Zürich's societal risk results with other airports are also presented. Section 4 gives a discussion of the results and finally, in section 5, a few conclusions are drawn.

2 Methodology of risk assessment

The methodology applied in the assessment of third party risk is in accordance with that used in the NLR risk analysis for Zürich airport in 2011 (Ref. 1). This includes the use of the NLR third party risk model standard for large airports and the application of the specific accident rates derived for Zürich-like airports. A comprehensive description of the methodology adopted in the NLR third party risk model is given in reference 2.

The Zürich-like airports comprise Zürich airport itself and 65 comparable Western airports. The Western airports that are considered to be comparable with Zürich are based on a number of selection criteria. These include the traffic volume, the presence of airport equipment (terminal approach radar, automatic terminal information system (ATIS), and meteorological information for aircraft in flight (VOLMET)), and the geographical location (Europe and North-America).

The NLR risk model consists of three components: accident probability (accident rates), accident location and accident consequences (see Figure 2-1). As mentioned previously, the accident rates applied here in the assessment are obtained from the set of 66 airports, including Zürich. The accident location and the accident consequences in the NLR risk model were derived from an extensive set of data concerning aircraft accidents, operations and airports worldwide. These data, which also encompass the data in the derivation of accident rates for Zürich-like airports, are extracted from the NLR Air Safety Databases.

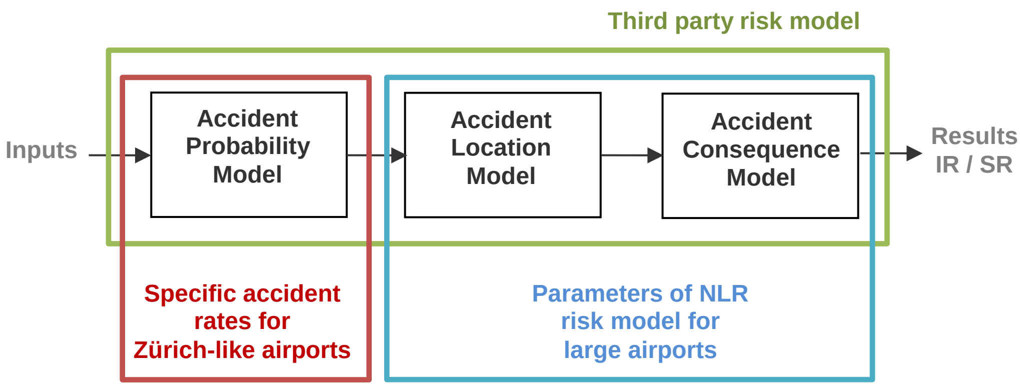

Figure 2-1: A schematic representation of the third party risk model applied in the assessment of third party risk around Zürich airport

The accident types considered in the third party risk model are (i) take-off overshoot, (ii) take-off overrun, (iii) landing undershoot, and (iv) landing overrun. These four accident types are depicted in Figure 2-2.

By definition veer-offs during take-off or landing are also third party risk accident types. However in a standard risk assessment veer-offs are not considered because on large international airports (like Zürich and Amsterdam Schiphol) considerable space is available on the sides of a runway where an aircraft could stop in case of a veer-off. Risk of veer-offs is therefore assumed to be limited to the terrain within the airport boundary and not to pose risk to third-parties.

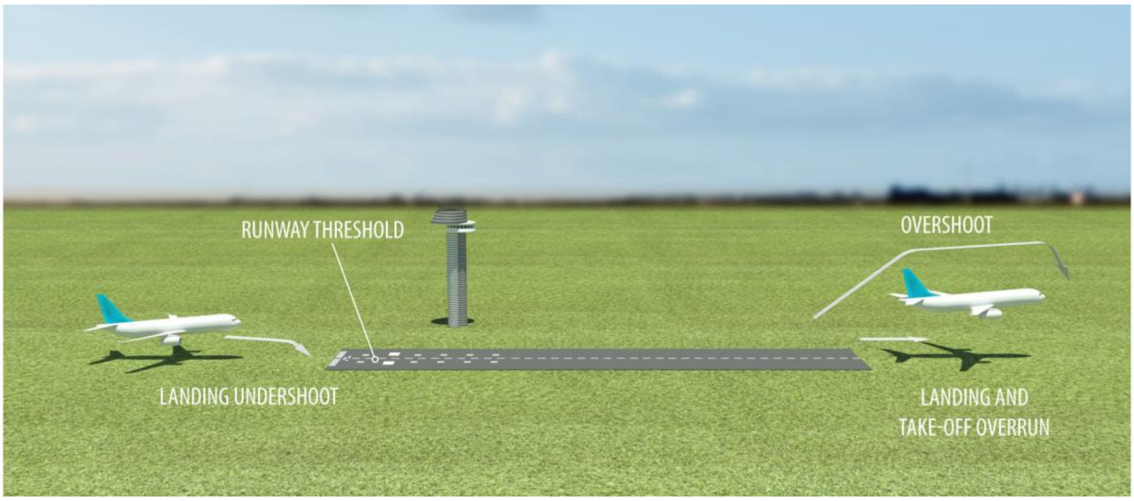

Figure 2-2: The accident types used in the NLR Third Party Risk model: landing undershoot, landing overrun, take-off overshoot and take-off overrun

As mentioned in the Introduction, for the SIL Zürich variants both individual risk and societal risk are determined. The definition of individual risk and societal risk is given in Appendix A.

In order to calculate the risk around Zürich airport, input data are needed. Under the auspices of Flughafen Zürich AG, the input data for all nine SIL Zürich variants are provided to NLR for processing into calculation inputs. The risk calculation input data set is comprised of the following:

- ***The traffic fleet mix data for each variant.*** The traffic fleet mix data contain the number of movements (departures and arrivals) per aircraft type, and the information of those aircraft types. The movement data also indicate which runway and route for arrival and departure is used by the aircraft.
- ***The airport runways and flight routes.*** The airport runways including the use of landing displaced thresholds and the flight routes (ground projection of the nominal flight paths) are considered in the calculations as this information determines the risk distribution over the surrounding of the airport.

In the SIL Zürich variants, it is foreseen that runway 28 and runway 32 will be extended. These changes in runway use are taken into account in the risk calculations.

- ***The population densities.*** The data of population densities are required in particular for the calculations of societal risk. The population considered is located in different types of buildings or objects, like residence, office, school etc., and is discerned for daytime and night-time period. For the present societal risk calculation the population data files are those applied in the NLR risk study in 2011 (Ref. 1).

Appendix B presents a detailed description of the data applied in the risk calculations. Further, appendices C through E present the figures of flight routes, an overview of the aircraft types and their MTOW, and the number of movements per variant.

3 Results

This section presents the calculation results of individual risk and societal risk for the SIL Zürich variants considered. Appendix F presents the identifications for the risk calculations.

Individual risk is shown as contours, i.e. lines with iso-probability, on a geographical map showing Zürich airport and its surroundings. The risk contours considered in this risk assessment are $1 \cdot 10^{-5}$/year (1 per 100,000 years) and $1 \cdot 10^{-6}$/year (1 per million years). These two values are chosen in accordance with the study conducted in 2011.

Societal risk is displayed as a curve on a double-logarithmic scale showing the risk value (*F*) per year for groups with more than *N* persons. The groups considered in this assessment contain 10, 20, 40, 100, 200, 400 and 1,000 persons. The persons regarded in the societal risk calculations are located in the vicinity of Zürich airport and within the study area used in the risk assessment.

3.1 Individual risk

On page 16 to page 21, the individual risk contours of different SIL Zürich variants are presented. The risk contours of variant 1 are used as comparison basis.

Due to the difference in the number of air traffic movements, the use of runways and flight routes, the resulting risk contours are in general different for each SIL Zürich variant. However, since only the 10^{-5}/year and 10^{-6}/year risk contours are investigated, those differences might not be observable for some variants. In other words, the changes in the risk contours when comparing with those of variant 1 might only be significant for lower risk values.

For the sake of clarity of this report only the risk contours with significant changes are presented and discussed here.

3.1.1 Variant 1

Figure 3-1 depicts the plot of the individual risk contours for SIL Zürich variant 1.

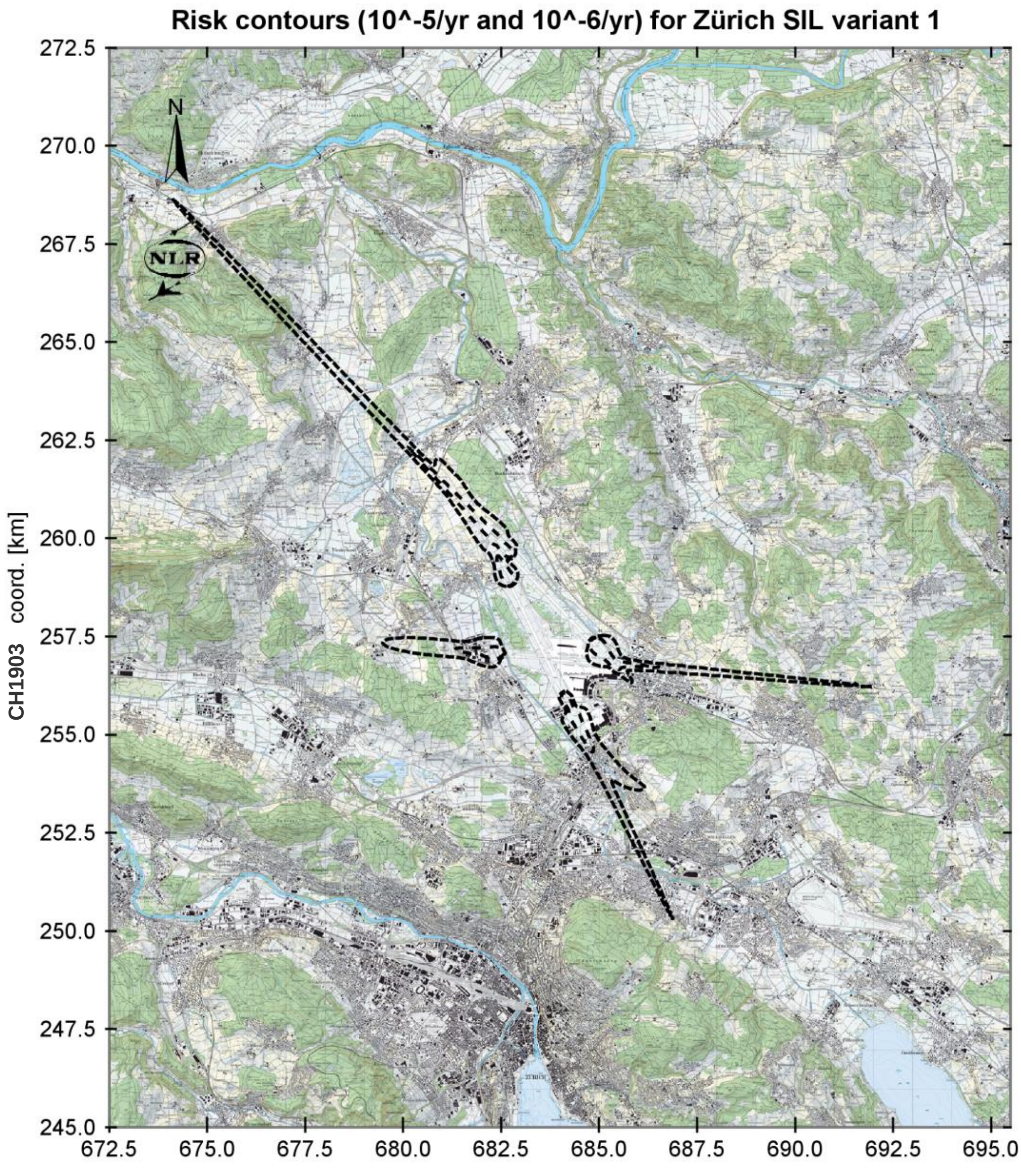

Figure 3-1: Individual risk contours of Variant 1: 10^{-5}/year (black, long dashed lines) and 10^{-6}/year (black, short dashed lines)

From the individual risk contours presented the following can be observed:

- The spiked 10^{-6}/year risk contours are due to arrivals on the runways.
- On the west side of the airport, at runway threshold 10, the risk contour is shorter and less spiked; it is only caused by departure traffic on runway 28 as there are no arrivals on runway 10.

- The 10^{-6}/year risk contour is the longest at the northwest of the airport; it is due to the large amount of arrival traffic on runway 14. The shortest 10^{-6} risk contour is located at runway threshold 32; this contour is a result of landing overrun risk on RWY 14.
- The effect of displaced threshold for arrivals on runway 34 is observable in contrast with that of runway 14 .
- The effect of extending runway 10-28 is observable; the 10^{-6}/year risk contour there lies outside the current runway location.
- The 10^{-6}/year contours cover part of different built-up and residential areas in the vicinity of the airport.
- To the south of the airport, at runway threshold 34, a bifurcation or branching in the 10^{-6}/year risk contours is observed. The pointed contour is caused by the arrivals, as mentioned before. The branched contour is attributed to the departure traffic on runway 16 following flight route turning to the left shortly after take-off.

3.1.2 Variant 2

Figure 3-2 presents a contour plot in which variant 2 is compared with variant 1. A marked difference can be observed in the distribution of individual risk between these variants.

- The risk contour of variant 2 at runway threshold 34 is significant larger than that of variant 1. This is due to the larger number of departures on RWY 16. As a result, the contour covers a larger part of built-up area south of the airport.
- The contours at runway 10 are much smaller for variant 2 due to the limited number of departures on RWY 28.
- No noticeable differences are found in the north-west (RWY 14 and RWY 16) and the east (RWY 28 and RWY 32).

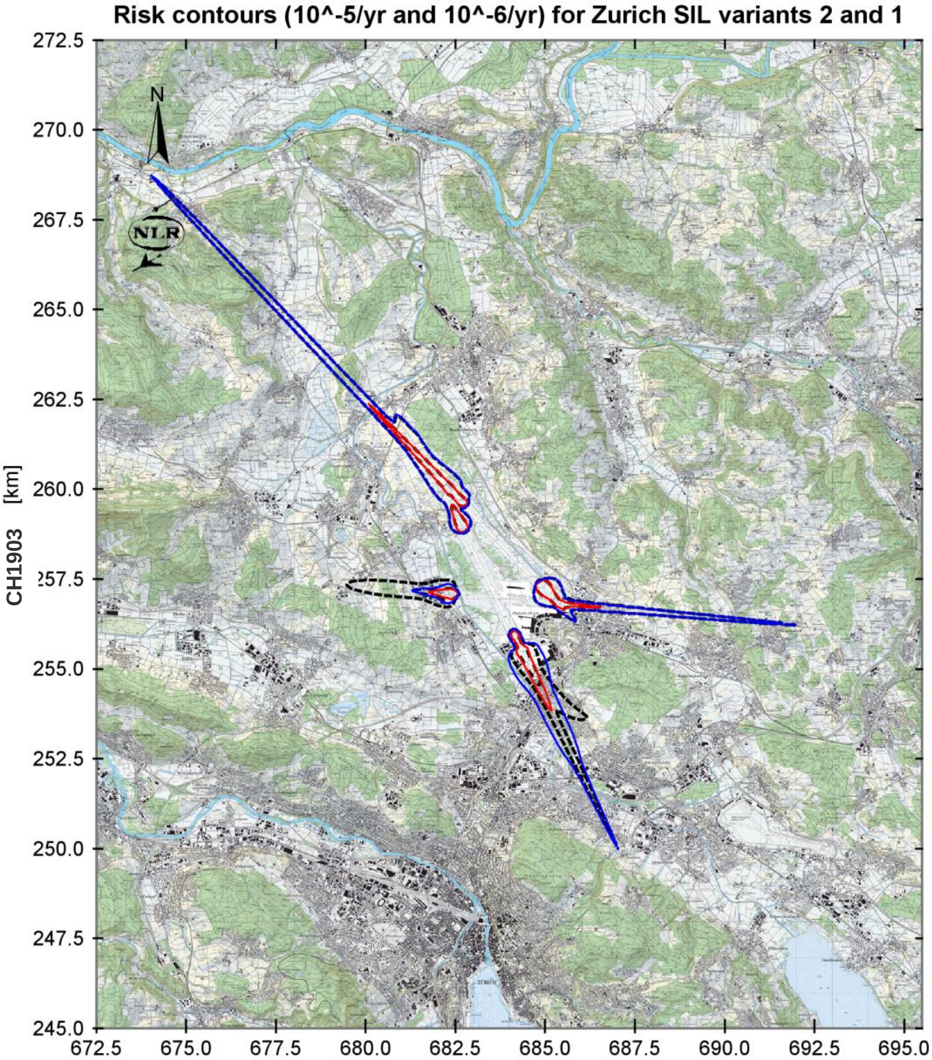

Figure 3-2: Individual risk contours of variant 2 with 10^{-5}/year (red) and 10^{-6}/year (blue) comparing with variant 1

3.1.3 Variant 3 and Variant 4

The differences between the (10^{-5}/year and 10^{-6}/year) risk contours of variant 3 and variant 4 with variant 1 are small. Hence, their contour plots are not presented here.

Variant 3 has almost the same number of movements and use of flight routes. Therefore the resulting risk contours are almost identical to those of variant 1.

Although variant 4 does not have departures on RWY 10, due to the fact that the number of arrivals on RWY 28 is more dominant and the fact that the accident rate of landing undershoot is higher than other rates of other accident types, the difference in the 10^{-5}/year and the 10^{-6}/year risk contours is not visible. Difference could only be observed by showing contours with lower risk values.

3.1.4 Variants 5a, 5b and 5c

Comparing the variants 5a, 5b and 5c with variant 1, the differences are more noticeable. The main differences are found in the comparison of variant 5b with variant 1 as shown in Figure 3-3. The bifurcation in the 10^{-6}/year contour on the south side of the airport is now hardly found in variant 5b (the same holds for variants 5a and 5c) due to a different use of flight routes from RWY 16. Also observed for variant 5b only are the smaller risk contours on the west of the airport. This is caused by a smaller number of departures on RWY 28.

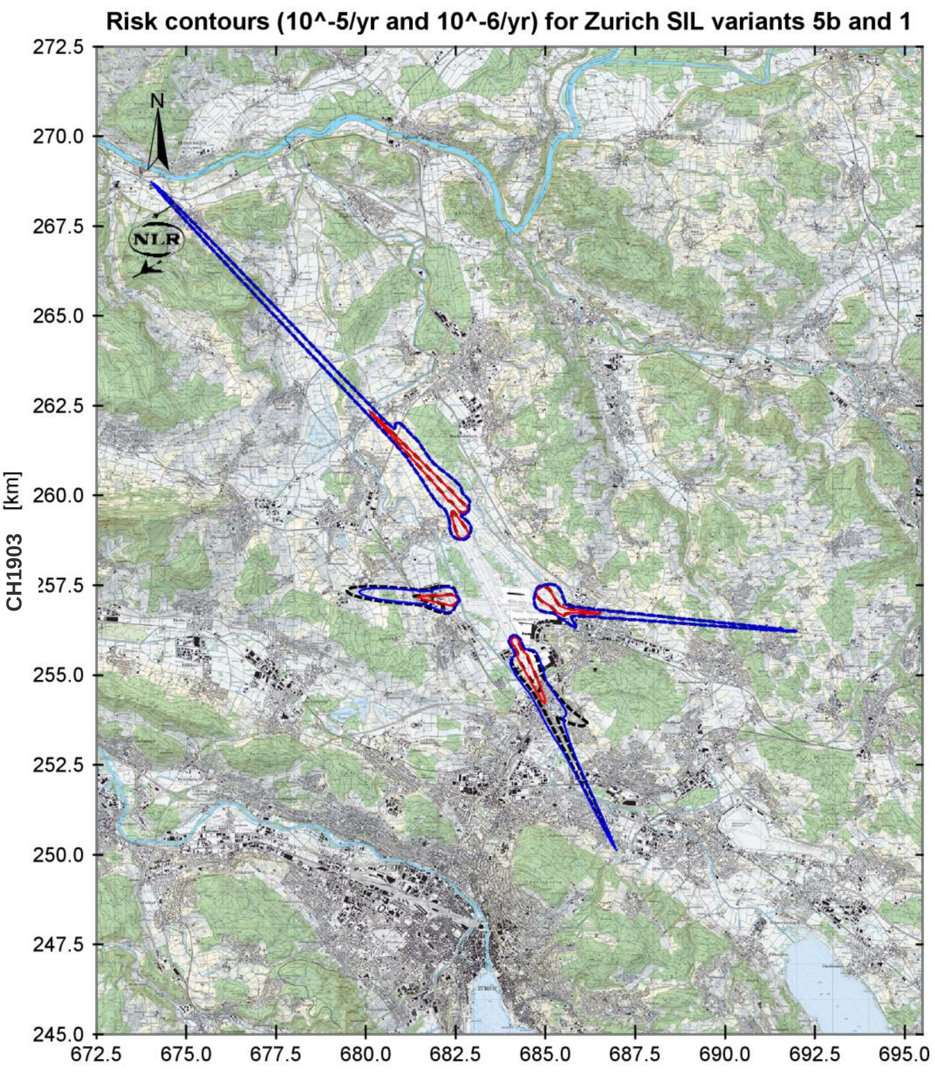

Figure 3-3: Individual risk contours of variant 5b with 10^{-5}/year (red) and 10^{-6}/year (blue) comparing with variant 1

3.1.5 Variant 6

Figure 3-4 presents a comparison of risk contours variant 6 with variant 1. Noticeable is the difference at runway threshold 34, the south side of the airport. Although variant 6 has more departures on RWY16, the different use of flight routes prevents the shaping of a bifurcation in the 10^{-6}/year contour.

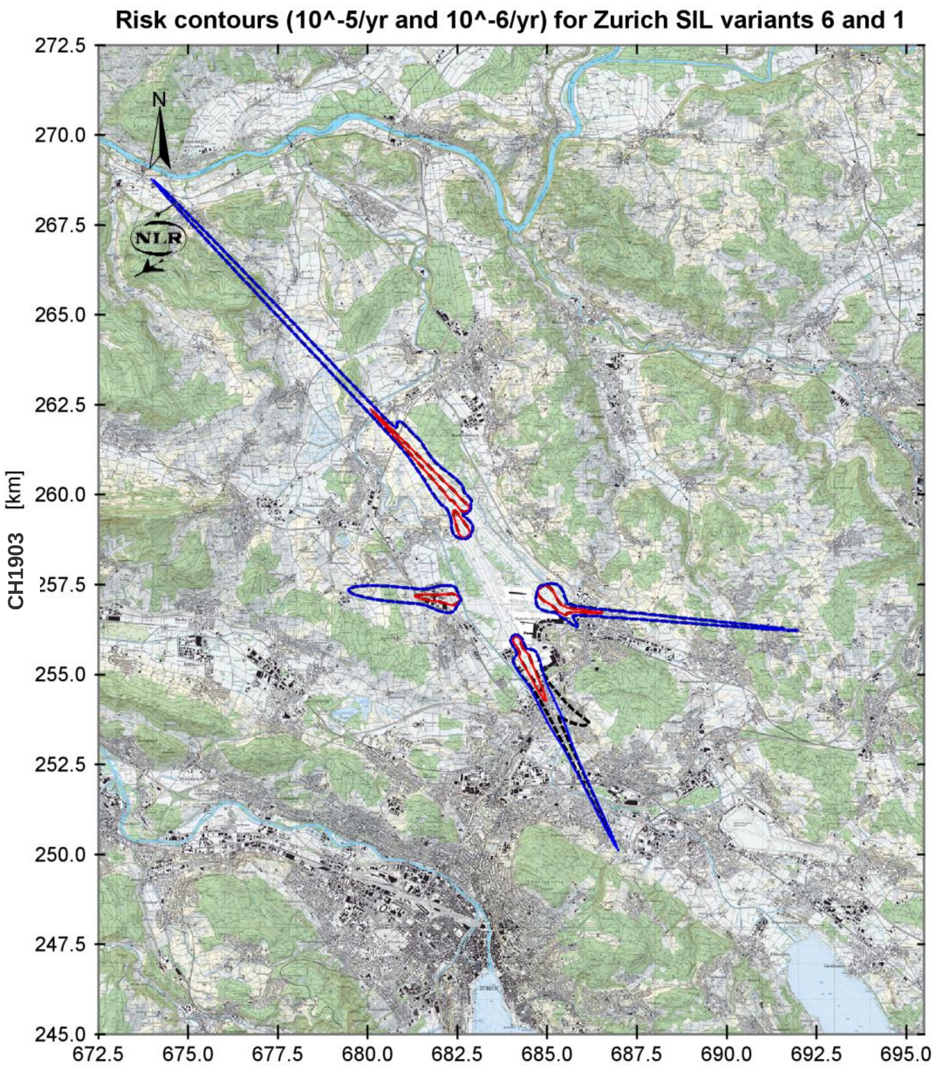

Figure 3-4: Individual risk contours of variant 6 with 10^{-5}/year (red) and 10^{-6}/year (blue) comparing with variant 1

3.1.6 Variant 7

Figure 3-5 depicts the individual risk contour plot with the comparison of variant 7 and variant 1. The individual risk contours of variant 7 are quite different from those of variant 1.

- The risk contours at the south of the airport are smaller. As a result, only a small area of residential area is covered. The bifurcation or branching of the risk contour is barely visible.
- At the east of the airport the risk contours are however longer and larger. Nonetheless, those contours seem not to extend to residential areas.
- On the contrary, at the north-west of the airport the spiked part of 10^{-6}/year risk contour is smaller and shorter. However, due to a slightly larger numbers of departures there, the bifurcation in the 10^{-6}/year contour increases in size. By visual inspection, the branch of the 10^{-6}/year risk contour extends to part of built-up area.

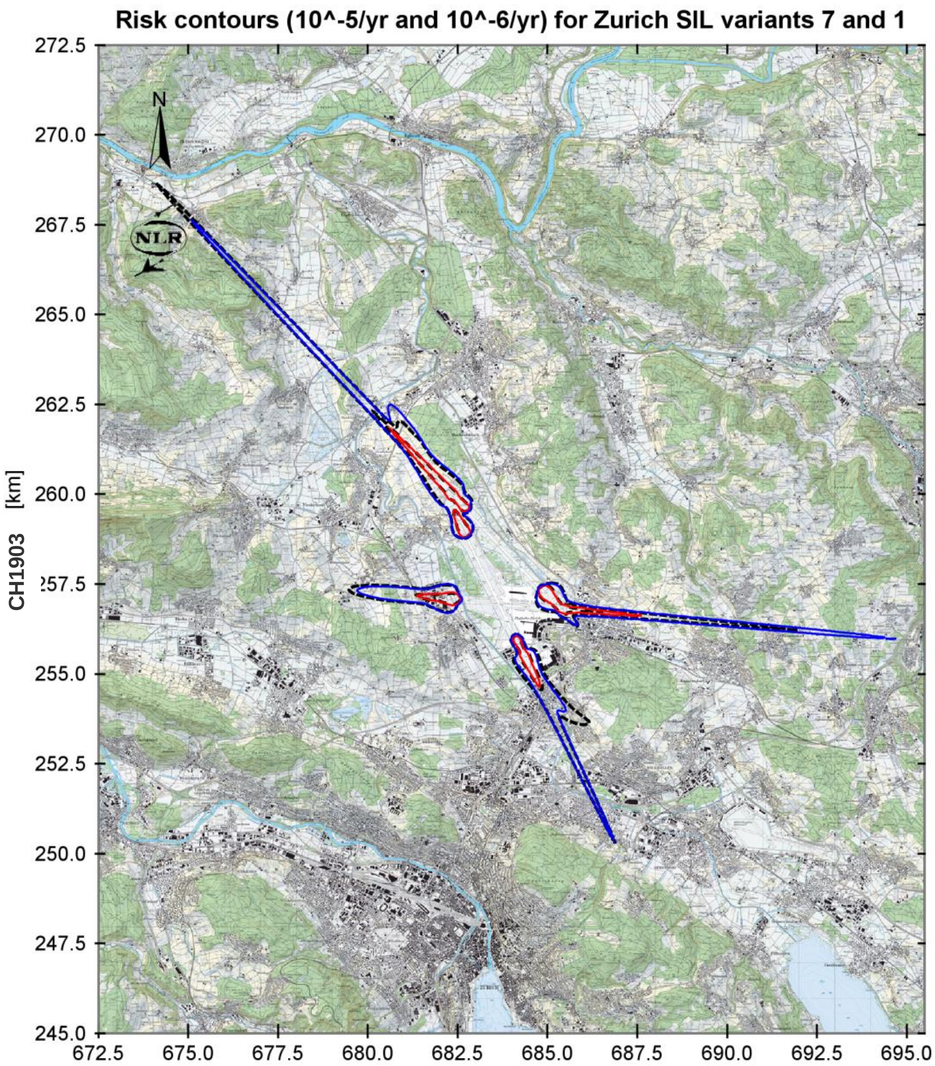

Figure 3-5: Individual risk contours of variant 7 with 10^{-5}/year (red) and 10^{-6}/year (blue) comparing with variant 1

3.2 Societal risk

The societal risk curves or FN-curves for all nine SIL Zürich variants are presented subsequently in Figure 3-6.

First by visual inspection of this figure, the societal risk curve of the SIL Zürich variants do not deviate much from each other. The curves are found within a narrow band following a certain pattern. The risk for smaller group sizes is higher than that for larger group sizes. This means that there is a smaller probability that an aircraft crash killing a large group of persons on ground takes place.

Differences among the variants can still be observed. The risk curve of variant 2 lies well above all other variants for each group size considered. On the contrary, the risk curve of variant 7 lies under all other variants. These two variants form apparently the upper and the lower bound where the risk curves of all other variants lie in between.

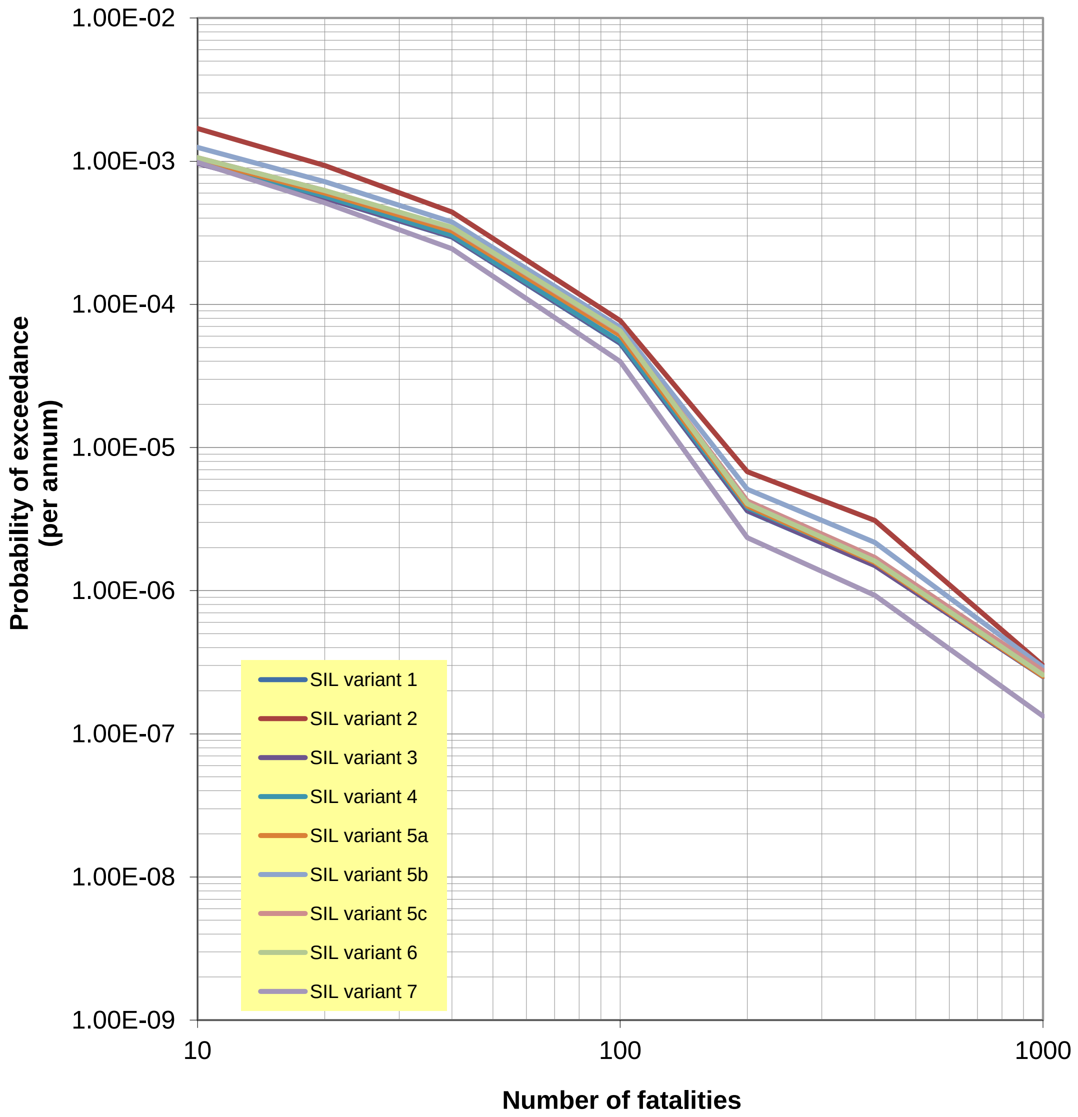

Figure 3-6: Societal risk curves or FN-curves for the nine SIL Zürich variants

Figure 3-7 presents the FN-curves of variants 1, 2 and 7, and that of the actual year situation in 2009. The latter is obtained from the 2011 risk study. From this figure it can be seen that the risk of SIL Zürich variants is higher than the situation in 2009 because of the larger number of movements in the scenario and the different flight routes used. For larger group sizes (400 or more), the risk of SIL Zürich variant 7 is comparable to that of the actual year situation despite the fact that the SIL variant has much more traffic.

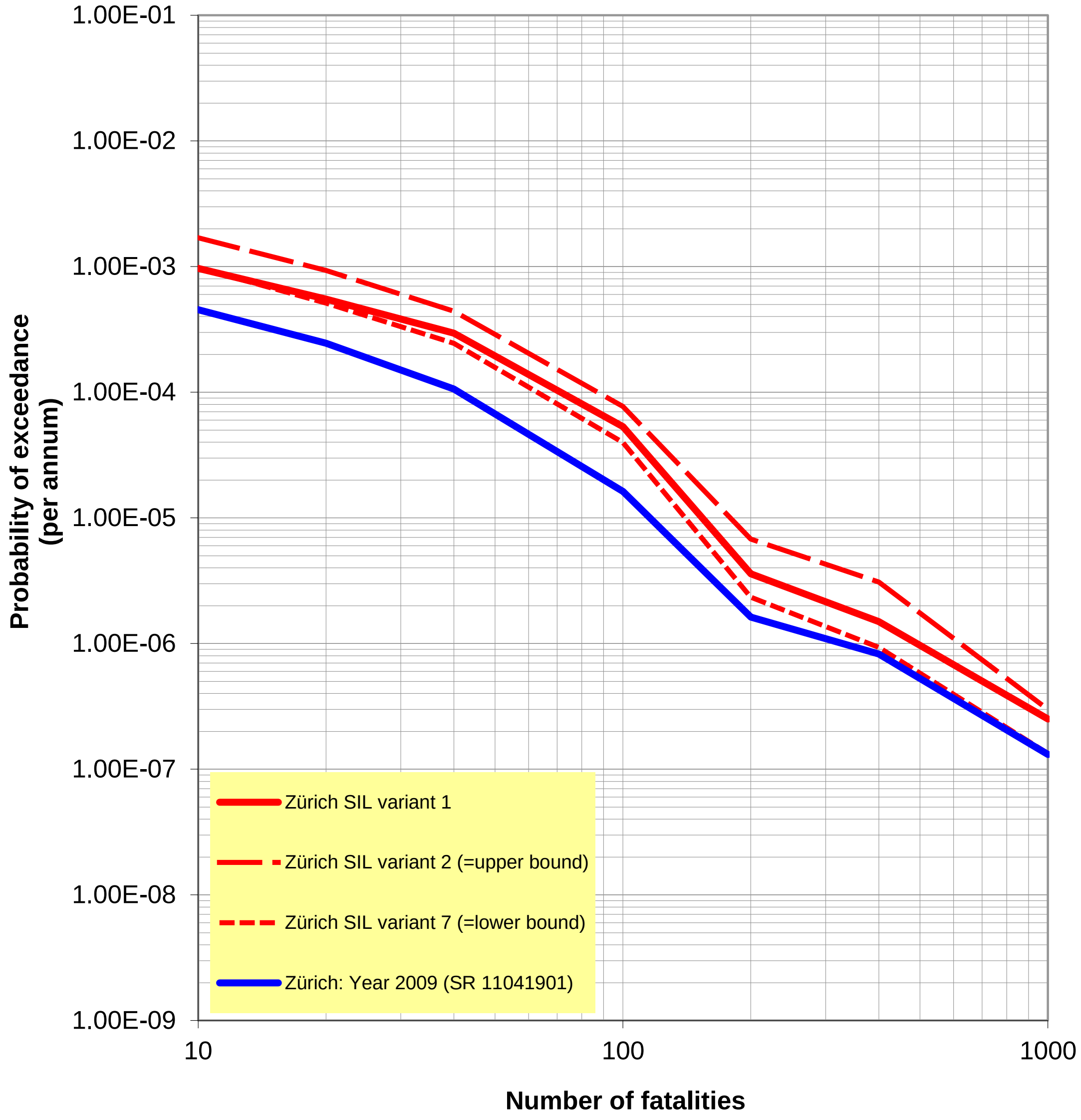

Figure 3-7: Societal risk curves or FN-curves for SIL Zürich variants 1, 2 and 7 comparing with Zürich Year 2009 situation

3.3 Comparison analysis of societal risk

The societal risk of SIL Zürich variants is further investigated and compared. Since the societal risk results as discussed in section 3.2 are examined visually, the discussion of comparison for that would be unilateral. Therefore complementary comparison tools may be deemed necessary.

For comparing the societal risk of the SIL Zürich variants, two comparison tools are devised. The first one is the application of bar-plot by showing all variants with respect to a reference variant, i.e. variant 1. The second one is the application of spider-plot by showing separately the risk of each variant compared with that of the reference variant.

Furthermore, to demonstrate the magnitude of risk that Zürich airport attains, the Zürich's risk is put into comparison with other western international airports for which societal risk has been determined before. The comparison is based on the *FN*-curve only. The order of magnitude of risk is briefly discussed.

3.3.1 Bar-plot comparison of societal risk

To demonstrate how each SIL Zürich variant performs, a comparison of societal risk is needed. Since there is no universal standard or criterion for comparing societal risk due to air traffic or for airport, SIL Zürich variant 1 is taken here as a reference. The purpose of such comparison is to show the performance of the SIL Zürich variants in terms of societal risk.

The performance is measured by the percentage change in risk per group size with respect to variant 1 (chosen as reference). The following simple relation per group size is adopted:

$$\%Change\ in\ risk = \frac{risk\ value\ of\ variant\ i - risk\ value\ of\ variant\ 1}{risk\ value\ of\ variant\ 1} \times 100\%$$

where i = variant number 2, 3, 4, 5a/b/c, 6 or 7.

This relation shows the amount of change in risk for a group of persons for each variant comparing with the risk for variant 1. A positive percentage of change means in this regard an increase in risk. In other words, variant i has higher risk than variant 1 for certain group size. A negative percentage means a decrease in risk: variant i has then lower risk.

Figure 3-8 shows the bar-plot of societal risk per group size for each variant in comparison with the reference, variant 1.

The bar-plot takes simultaneously all variants in comparison with variant 1 and takes all group sizes in consideration. In addition, the plot shows at once the changes in societal risk.

From this figure it can be seen that variant 2 has a higher societal risk than the reference whilst variant 7 has a lower risk. After variant 2, variant 5b seems to have higher risk than the other variants. In general, except for variant 7, all other variants have higher societal risk values than variant 1 for the group sizes considered.

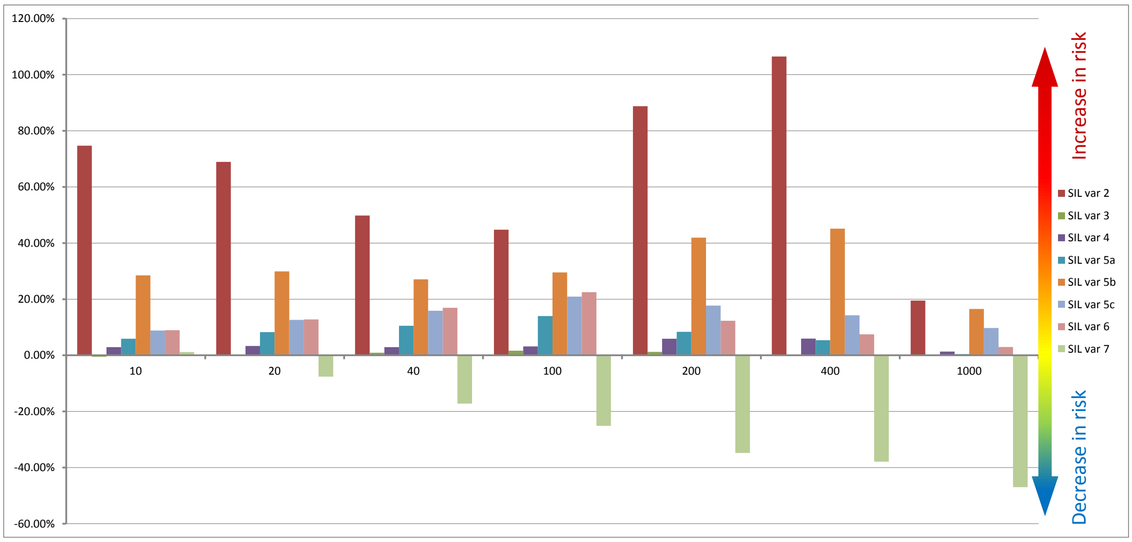

Figure 3-8: Comparison of all variants with variant 1 across different group size (societal risk)

3.3.2 Spider-plot comparison of societal risk

Spider-plots or spider-charts are adopted here to compare each variant with the reference, variant 1. The spider-plots as displayed in Figure 3-9 through Figure 3-16 are constructed with the following steps:

- The risk values per group size for variant 1 are first normalized which means the risk value for each group size considered, i.e. 10, 20, 40, 100, 200, 400 and 1000, is set to 100%.
- The risk values per group size for the variant considered are compared to those of variant 1 (chosen as reference). The ratio is determined as percentage with the following relation:

$$Percentage\ for\ each\ group\ size = \frac{risk\ value\ of\ variant\ i}{risk\ value\ of\ variant\ 1} \times 100\%$$

where *i* = variant number 2, 3, 4, 5a/b/c, 6 or 7.

- Two curves in the spider-plot are then drawn: one for variant 1 and one for variant *i* considered.

The advantage of this way of presenting the societal risk is that one can observe at a glance how each variant changes with respect to the reference, variant 1. If, for instance, for each group size the risk value of the variant considered is larger than those of variant 1, its curve (spider-plot) would then be larger and encompass the curve of variant 1.

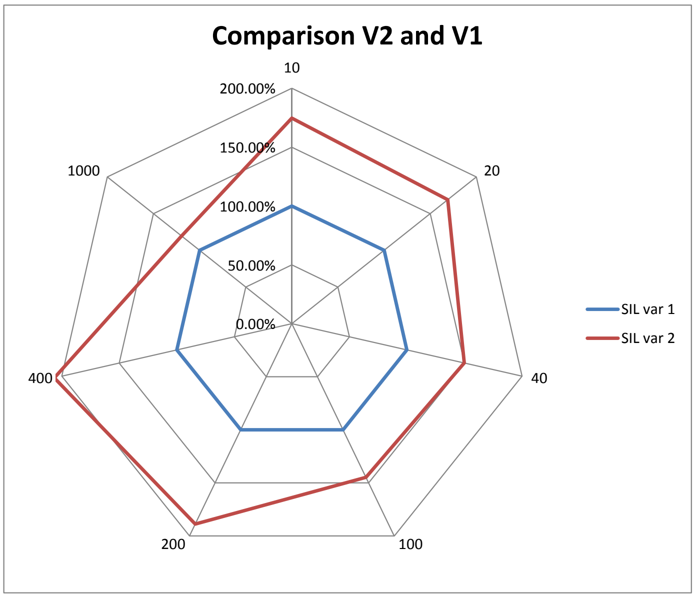

Figure 3-9: Spider-plot with comparison of variant 2 and variant 1

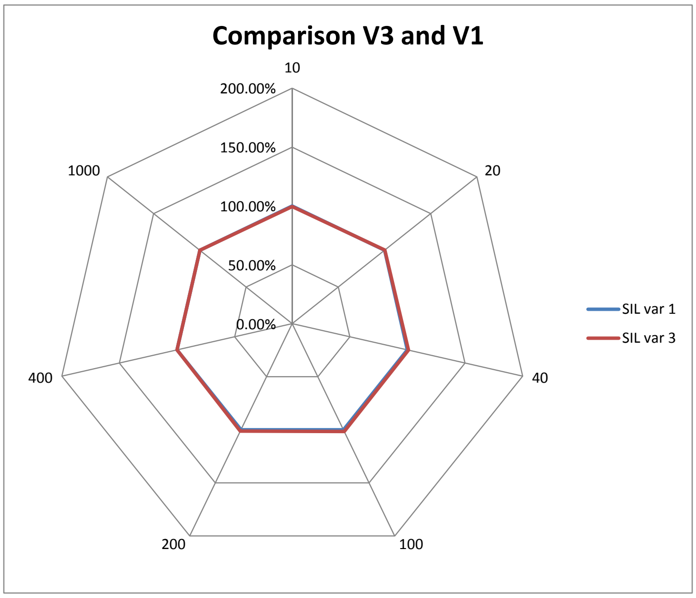

Figure 3-10: Spider-plot with comparison of variant 3 and variant 1

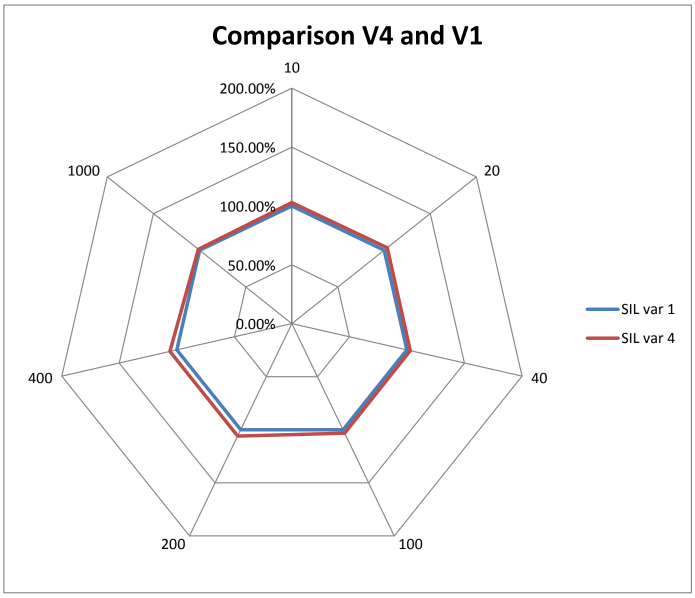

Figure 3-11: Spider-plot with comparison of variant 4 and variant 1

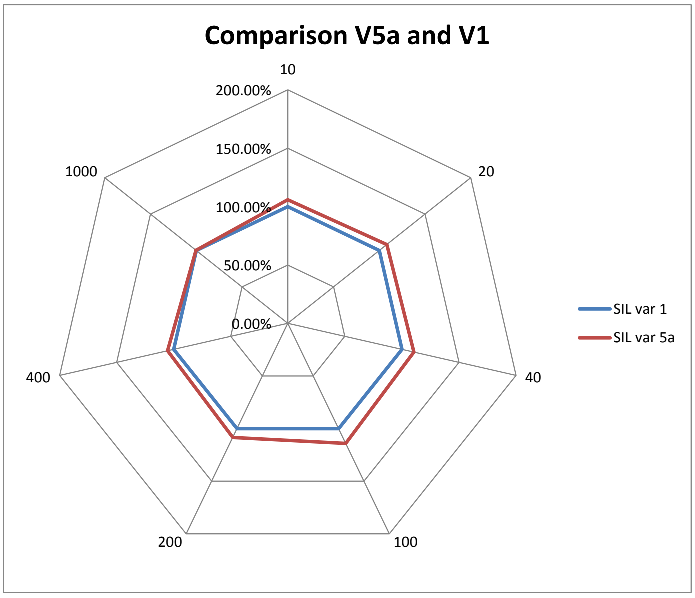

Figure 3-12: Spider-plot with comparison of variant 5a and variant 1

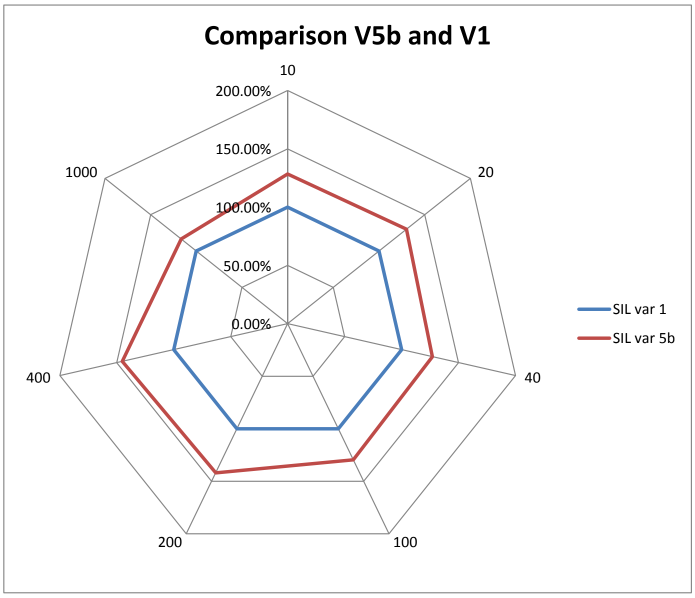

Figure 3-13: Spider-plot with comparison of variant 5b and variant 1

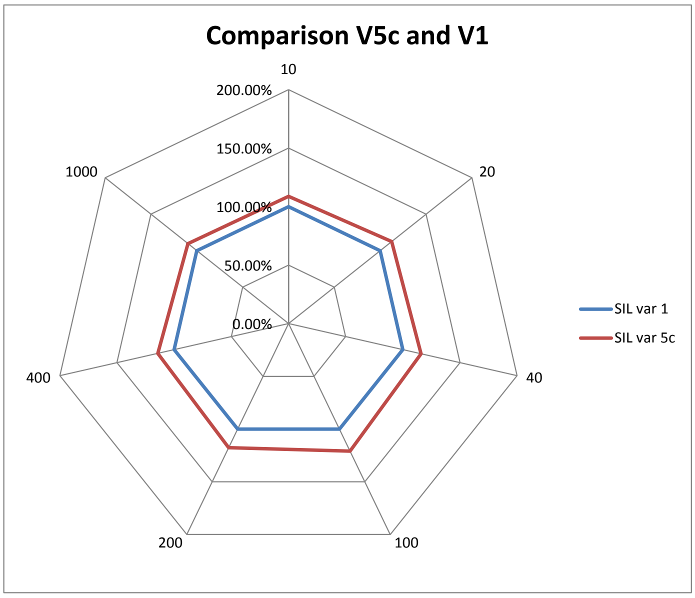

Figure 3-14: Spider-plot with comparison of variant 5c and variant 1

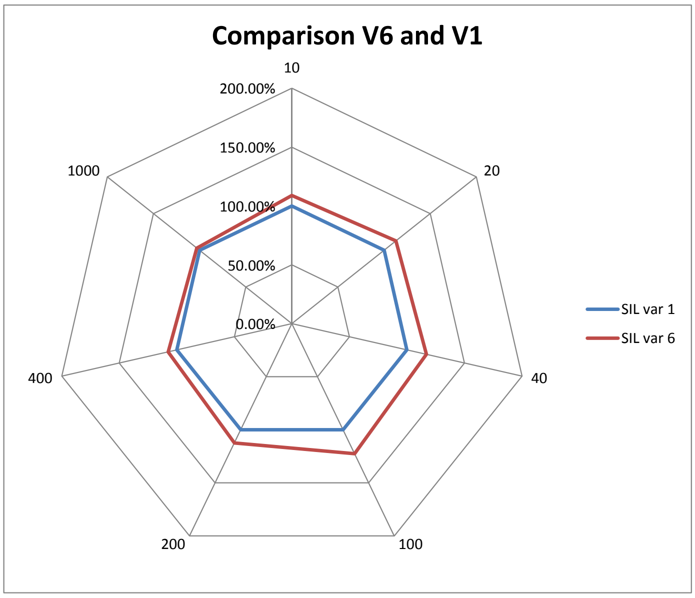

Figure 3-15: Spider-plot with comparison of variant 6 and variant 1

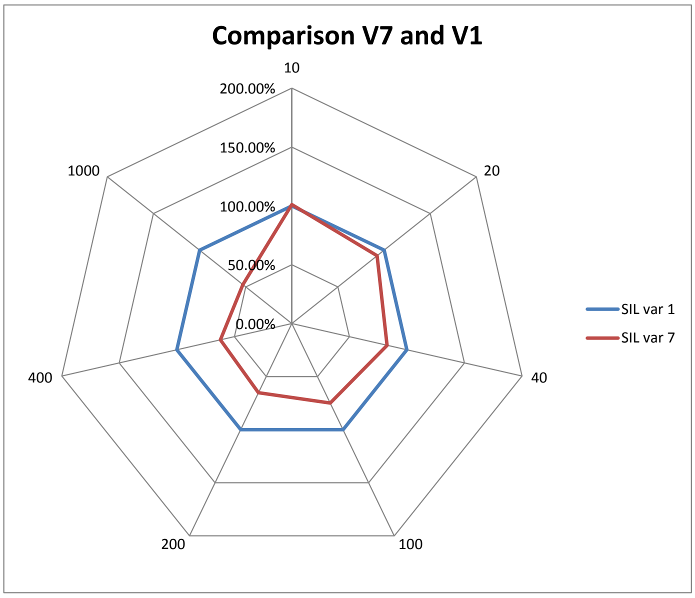

Figure 3-16: Spider-plot with comparison of variant 7 and variant 1

From the subsequent figures shown in Figure 3-9 through Figure 3-16, the following is observed:

- Variant 2 has the largest spider-plot for the group sizes considered.
- Variant 7 is the only variant that has a smaller spider-plot than variant 1.
- The spider plot of variant 3 is almost identical to that of variant 1.

- The plots of variant 4 and variant 1 are quite comparable. Only for larger group sizes (200, 400) the plot of variant 4 is slightly larger than variant 1.
- By observing the plots of variants 5a, 5b and 5c comparing with variant 1: the plot of 5b is the largest of the three, and the plot of 5c is somewhat larger than 5a.
- Variant 6 has a larger plot than variant 1. However, for group of 1000 persons, the plots of these two variants seem to coincide. In other words, the risk for a group of 1000 people is comparable for both variants.

3.3.3 Comparison of Zürich and other airports

A comparison of the societal risk of Zürich is made with the risks of other airports. The purpose of this comparison is to demonstrate the level or the order of magnitude of the risk that Zürich airport attains in comparison with other western international airports.

Figure 3-17 shows the societal risk curves (*FN*-curves) of different airports. The societal risk curves in this figure are derived from a variety of sources or references as follows:

- The risk curves of SIL Zürich variants in the present study.
- The risk curves of Schiphol airport (Ref. 3) and Western airports 1 and 2 are derived from various NLR studies. The names of both Western airports are withheld due to confidentiality.
- The risk curves of Heathrow, Sydney, Manchester and Frankfurt are obtained from an NLR-study in which the societal risks of these airports were compared with Schiphol's (Ref. 4). The sources of the risk curves are in their turn derived from a number of risk analysis reports available to NLR.
- The risk curve of Base-Mulhouse is determined by NLR using reference 5 and only the groups 10, 20, 40, 100, 200, 400 and 1000 are regarded.

In the figure, the societal risk curves of SIL Zürich variant 1, 2 and 7 are depicted in red solid line, long dashed line and short dashed line, respectively. Other variants of SIL Zürich are not shown because variants 2 and 7 form well for the group sizes 10 through 1000, the upper bound and lower bound of the societal risk curves in which the risk of other SIL Zürich variants lie in between. The risk curve of variant 1 is shown here as a reference.

From this figure it can be seen that the Zürich airport's societal risk is not exceptional in comparison with other airports.

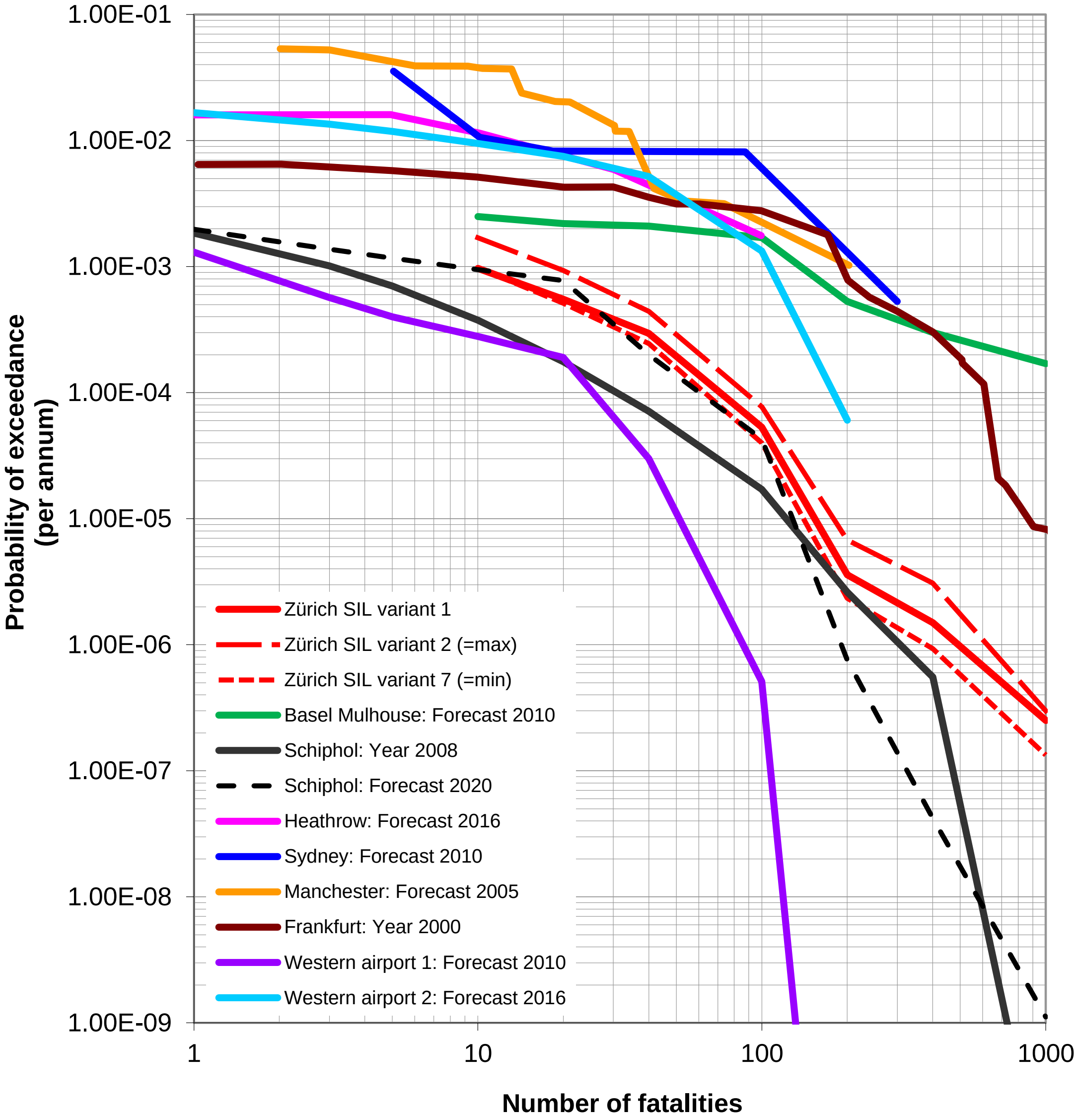

Figure 3-17: Comparison of societal risk curves or FN-curves of a number of airports

4 Discussion of results

In this risk assessment for SIL Zürich variants, the Individual risk is calculated and risk contours are determined. Due to the different number of movements and use of flight routes and runways, some differences in the resulting risk contours are observed. However, because of the levels of risk contours chosen in this study, the differences for some variants are not entirely detectable and are thus not significant. Therefore the information of individual risk is not easy to grasp in comparing the variants.

Societal risk is calculated and *FN*-curves are determined for the SIL Zürich variants as well. The resulting *FN*-curves show a narrow band in which the risks of the SIL Zürich variants lie in between. The societal risk curves are in general quite comparable and do not deviate much.

By evaluating the societal risk in detail, however, differences between the variants can be observed. The differences are shown by using the bar-plot and spider-plot presentations of the societal risk for the groups of people considered. By combining the results of both bar-plot and spider-plot presentations the results show clearly that variant 7 gives the lowest (societal) risk whereas variant 2 the highest. Variant 7 is thus the most favourable SIL Zürich variant in terms of risk. Following variant 7 are variants 3 and 4 as they present the risk levels almost identical to that of variant 1.

In addition to the mutual comparison of the SIL Zürich variants, the societal risk of Zürich airport is also put into comparison with other airports. The result shows that overall the societal risk curve of Zürich airport is not exceptional. In other words, the order of magnitude of Zürich risk is comparable with a number of western international airports.

5 Conclusions

Individual risk

- The resulting individual risk contours show that 10^{-6}/year contours cover part of the built-up and residential areas in the surroundings of the airport.
- The individual risk contours do not form easy-to-grasp risk information for comparing variants. This is because some variants have quite comparable traffic situation as that of the reference situation, variant 1, and the levels of risk contour that are chosen in this study are limited to 10^{-5}/year and 10^{-6}/year. Therefore the differences may not be significant for some variants.

Societal risk

- The resulting societal risk curves of different SIL Zürich variants lie in a narrow band and they do not deviate much.
- In the comparison of societal risk curve of Zürich with other western international airports, Zürich's curve shows a comparable pattern and is not exceptional.
- By evaluating the societal risk in detail, however, it is found that of all SIL Zürich variants, variant 2 has the highest risk for the group sizes considered. Variant 7 has the smallest risk and is the only variant that has smaller risk than variant 1. All other variants have risk that is either identical to or higher than variant 1.

6 References

1. *An analysis of third party risk around Zürich Airport, With a derivation of specific accident rates,* NLR report NLR-CR-2011-081 (Company confidential), Y.S. Cheung, J.A. Post and L. de Haij, November 2011.

2. *An enhanced method for the calculation of third party risk around large airports, with application to Schiphol,* NLR report NLR-CR-2000-147, A.J. Pikaar, C.J.M. de Jong and J. Weijts, April 2000.

3. *Strategische Milieuverkenning voor de ontwikkeling van Schiphol op middellange termijn,* Schiphol Group and LVNL, najaar 2008 (report in Dutch).

4. *Externe veiligheid luchthaven Schiphol 2001 en groepsrisico rond diverse luchthavens: bijlage voor de Milieubalans 2002,* NLR-CR-2002-237, J. Weijts and M.K.H. Giesberts, August 2002 (report in Dutch).

5. *Risikoanalyse für den Flughafen Basel-Mülhausen – Kurzfassung,* (web document), GfL (Berlin) and Arcadis Trischler & Partner GmbH (Darmstadt), June 2001 (report in German).

6. *An overview of quantitative risk measures for loss of life and economic damage, Journal of Hazardous Materials A99 (2003) 1 -30*, S.N. Jonkman, P.H.A.J.M. van Gelder and J.K. Vrijling, 2003.

Appendix A Risk metrics

Individual risk (IR) is defined as the local probability per year that a person, who is permanently residing at this particular location, suffers fatal injury as a direct consequence of an aircraft accident on or near his/her position.

Two important characteristics of the Individual Risk are:

- Individual Risk represents a point-location risk; it is calculated separately for every location around the airport and differs from location to location.
- Individual Risk is independent of the actual population around the airport; it is calculated for a fictive person who is presumed to stay permanently in one single location.

Societal Risk (SR) is defined as the probability per year that a group larger than a given number of persons (third parties) is killed due to a single aircraft accident. Societal Risk is presented as an *FN*-curve, where *F* (frequency)[1)] stands for the probability per year and *N* stands for the group size. Due to the wide range of values of probability and group sizes, the *FN*-curve is practically plotted on a double-logarithmic scale. In practice, only a selected number of group sizes is calculated, for example, $N \in \{1, 3, 5, 10, 20, 40, 100, 200, 400, 1000\}$.

Two important characteristics of the Societal Risk are:

- Societal Risk represents the risk over the total study area around the airport.
- Societal Risk depends on the actual population distribution around the airport; in a hypothetical situation where no population is present anywhere around an airport, the Societal Risk for this airport would be null (zero).

The essential difference between Individual Risk and Societal Risk is shown in Figure A.1. Depicted in the figure are two situations, A and B, with an identical risk source. Although both situations could have the same individual risk as a consequence of the risk source, due to the different population distributions in the surrounding of the risk source, situation B has larger societal risk than situation A. It may be clear that the use of both main risk metrics can be important in expressing third party risk.

[1)] In terms of statistics this quantity is a frequency that depends on the distribution of group sizes in the population sample.

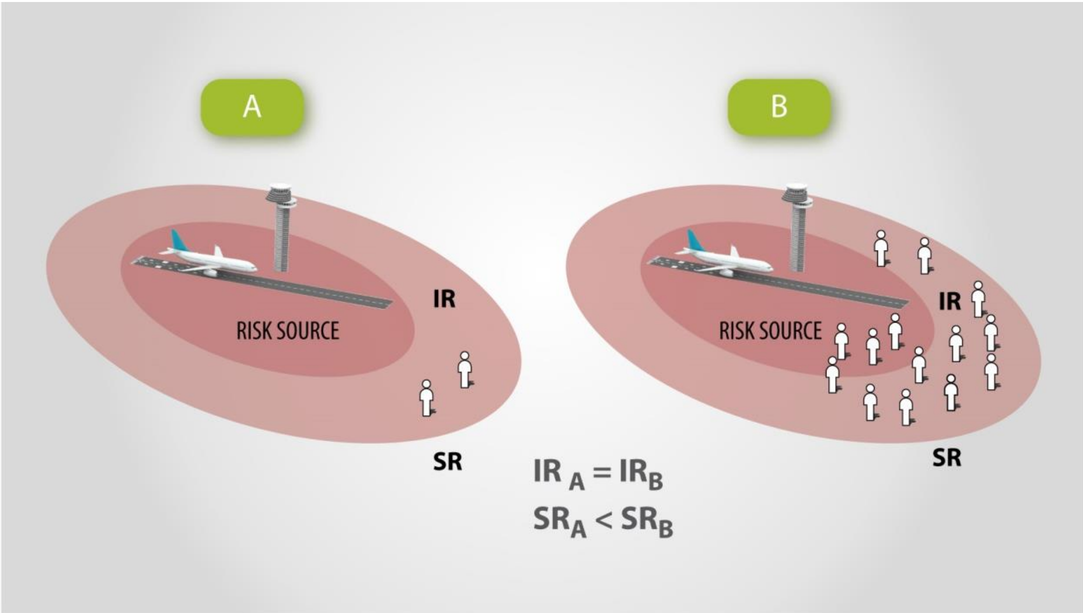

Figure A.1: Difference between Individual Risk (IR) and Societal Risk (SR). The Individual Risk levels are for situation A and B the same. However, due to the different distribution of population, Societal Risk for situation B is higher than that for A. Figure is adapted from reference 6

Appendix B Overview of input data

Appendix B.1 Coordinate system, study area and grid size

For the coordinate system, the Swiss Bessel CH1903 Datum reference system (CH1903) is used. The study area in which the third party risk for Zürich airport is assessed, is a square area of 40km by 40km, with the airport located in the approximate centre. The boundaries of the study area are defined by the coordinates of the lower-left corner and the upper-right corner of the square. Table B.1 presents the coordinates in metres.

Table B.1: Coordinates of the lower-left and upper-right corners of the study area

Corner	X-coordinate	Y-coordinate
Lower-Left	663700	237200
Upper-Right	703700	277200

The study area is further divided into small calculation cells. The size of the cell used in the risk calculations is set to 50×50 square metres. Risk value is calculated for the centre of each calculation cell.

Appendix B.2 Airport runways

For all SIL Zürich variants considered, there are a couple of changes in airport runways with respect to the current situation. According to the information of Flughafen Zürich AG, runway 28 and runway 32 will be extended in the future and the risk analysis shall take into account these changes.

The extension of runway 28 is 400 metres, the runway 28-10 would then become 2900 metres long. The extension leads to a relocation of the departure end of runway 28, the threshold of runway 10 and the coordinates of the runway 10 move to the west.

The extension of runway 32 is 280 metres and the runway 32-14 becomes 3580 metres long. This extension means that the coordinates of the runway 14 will be relocated to the north. Further, according to the information provided by the airport, the displaced landing threshold (DTHR) for runway 14 remains on the current location.

The runways and the accompanied coordinates that are used in the risk assessment are presented in Table B.2. The coordinates of runway 10 are provided by Flughafen Zürich AG in the departure flight route data. The coordinates of runway 14 are determined by NLR by extending the runway with 280 metres to the North. These coordinates are delivered to Flughafen Zürich for confirmation. The remaining coordinates are derived from the previous risk study in reference 1.

Table B.2: Coordinates of the airport runways

Runway	X-coordinate	Y-coordinate	Description / Remark	Runway length
10	682458.1	257077.7	10-28 for take-off*	2900 metres
28	685347.3	256816.8	28-10 for both take-off and landing	2900 metres
14	682419.0	259925.6	14-32 used for take-off on 14, if any**	3580 metres
14(DTHR)	682715.5	259614.2	14D-32 for landing on 14 with DTHR	3150 metres
32	684888.1	257332.0	32-14 for take-off***	3580 metres
16	682715.1	258904.9	16-34 for take-off and landing on 16	3700 metres
34	684326.7	255574.8	34-16 for take-off on 34	3700 metres
34(DTHR)	684129.1	255985.1	34D-16 for landing on 34 with DTHR	3245 metres

*) Take-offs on RWY 10 are only for SIL Zürich variant 1 and variant 3, and there are landings on RWY 10.

**) In the SIL Zürich variants there are no take-offs on RWY 14.

***) There are no landings on RWY 32 in the variants.

Appendix B.3 Flight routes

The departure flight routes are delivered by Flughafen Zürich AG and the arrival flight routes are derived from the risk study in 2011 (Ref. 1). The arrival flight routes in this risk study were provided by FOCA and were originally delivered by the airport.

The flight route data for departures are provided by Flughafen Zürich AG in CAD file format DXF. The departure routes contain nominal routes and they are derived from the tracks data as used in the airport noise calculations for the SIL Zürich variants. In the risk calculations, aircraft departing from Zürich airport are assumed to follow the nominal routes.

For arrivals, route data are initially provided by the airport. These route data contain vectoring paths for approach over a large area around the airport and end at a far point on the extended line of the runway. However, no route data are provided from that point to the runway end. For the purpose of calculation of risk due to arrivals to Zürich, the arrival route data should be made complete. In consultation with Flughafen Zürich AG, the flight route data for arrivals for this risk assessment are therefore derived from those applied in the risk study in 2011 (Ref. 1). Those arrival routes consist of a number of straight-in ILS approach paths on four runways only, i.e. RWY 14, 16, 28 and 34. These approach paths extend through the point about the Final Approach Fix (FAF). Aircraft approaching to Zürich airport in the SIL variants are assumed to use one of these straight-in approach paths.

Appendix C presents the flight routes used in the present risk assessment.

Appendix B.4 Traffic and aircraft fleet mix data

The traffic data consists of aircraft types and aircraft movements per runway and route. Flughafen Zürich AG has initially provided a data set of the traffic as used in the noise calculations. Prior to the execution of risk calculations, NLR has analysed the information provided and considered that a number of adjustments in the data is necessary. In consultation with the airport, the following modifications are made:

- The representative aircraft types, which were applied in the noise calculations, are replaced by a set of detailed aircraft types as used in the design of the operational concept originally. In the risk assessment, the MTOW of each representative aircraft type for noise is replaced by the MTOW that is averaged over a range of detailed aircraft types and their movements within the same noise category of the representative aircraft type.
- The traffic data, which are provided in detail in different time blocks, are differentiated in daytime and in night-time periods. For day-time the period between 07-19 hours is assumed. For night-time the period 19-07 hours is assumed. This differentiation in day and night is only necessary for the societal risk calculations to demonstrate the effects of population located in different objects. During daytime, it is likely that people are more present at work (in offices, factories, schools etc.) than at homes (in residential areas). During night-time, it is likely the other way round.
  The traffic data are available for the time blocks 06-07, 07-21, 21-22 and 22-23. Between 23-06 no traffic is foreseen. In the determination of the daytime traffic, NLR assigned 12/14 of the traffic in the time block 07-21. The remaining 2/14 of the traffic in this time block together with traffic in the time blocks 06-07, 21-22 and 22-23 are assigned to the night-time traffic.

Appendix B.5 Aircraft maximum take-off weight data

The aircraft maximum take-off weight is an input parameter that determines the accident consequences in the risk model. The aircraft MTOW information applied in the risk calculations for Zürich airport is based on the official list of MTOWs that is used in the Environmental Information Regulation for Amsterdam Schiphol Airport. The data are derived from the authoritative "Jane's All the World's Aircraft" information.

Prior to the risk calculations, NLR has determined for each detailed aircraft type the correct MTOW by using the aforementioned source. Combining the MTOW information and the number of movements per detailed aircraft type in each WTC-category, the weighted MTOW for a noise representative aircraft can be determined.

Appendix D gives an overview of the MTOWs as used in the risk calculations. The MTOWs for the noise-representative aircraft type are the same for all SIL Zürich variants.

Appendix B.6 Population data

For a calculation of societal risk not only the data of traffic, flight route and aircraft weight are required (data as those used in the individual risk calculations), but also the data of population, i.e. the data on the people situated around the airport and in the study area. For the present societal risk calculations for SIL Zürich variants, the population data files as those applied in the previous NLR risk study (Ref. 1) are re-used.

These data files comprise a daytime population data set and a night-time population data set. It is assumed that the daytime population corresponds to the period as applied for the daytime traffic (07-19 hour) and the night-time population corresponds to that for night-time traffic (19-07 hour).

The daytime population includes people staying at home, employees, students (including commuters from other Swiss cantons). The source of the daytime population is the Statistisches Amt des Kantons Zürich (VESTA) and is a result of a scientific study, and is thus not an official population data set. The information of population is primarily based on the statistical data from Swiss population census of 2000 (BFS). NLR processed the data by assigning the population located in different objects (houses, offices, schools, etc.) to a calculation grid with population densities. Further, NLR adjusted the data by removing the ‘population’ located within the airport boundary. It is noteworthy that the set for daytime population covers the whole Canton of Zürich, but not the entire study area. For night-time population, the data set ZH2009 is used. The source of this set is obtained from the population census at the end of December 2009. Table B.3 presents the number of persons in each population data file.

Table B.3: Population data files and total number of persons

Population data file	Number of persons in data file
Daytime (ZH2000)	1124490
Night-time (ZH2009)	1131951

Appendix C Figures of flight routes

This appendix present the figures of the flight routes as used in the risk calculations for the SIL Zürich variants. The flight routes are presented on a larger area (85 by 75 sq.km) than the study area (40 by 40 sq.km). The purpose of this presentation is to clearly show the direction that each route for a departure and an arrival is following.

It is noteworthy that the map material available to NLR for presenting the figures is limited to a smaller area (approximately the size of the study area).

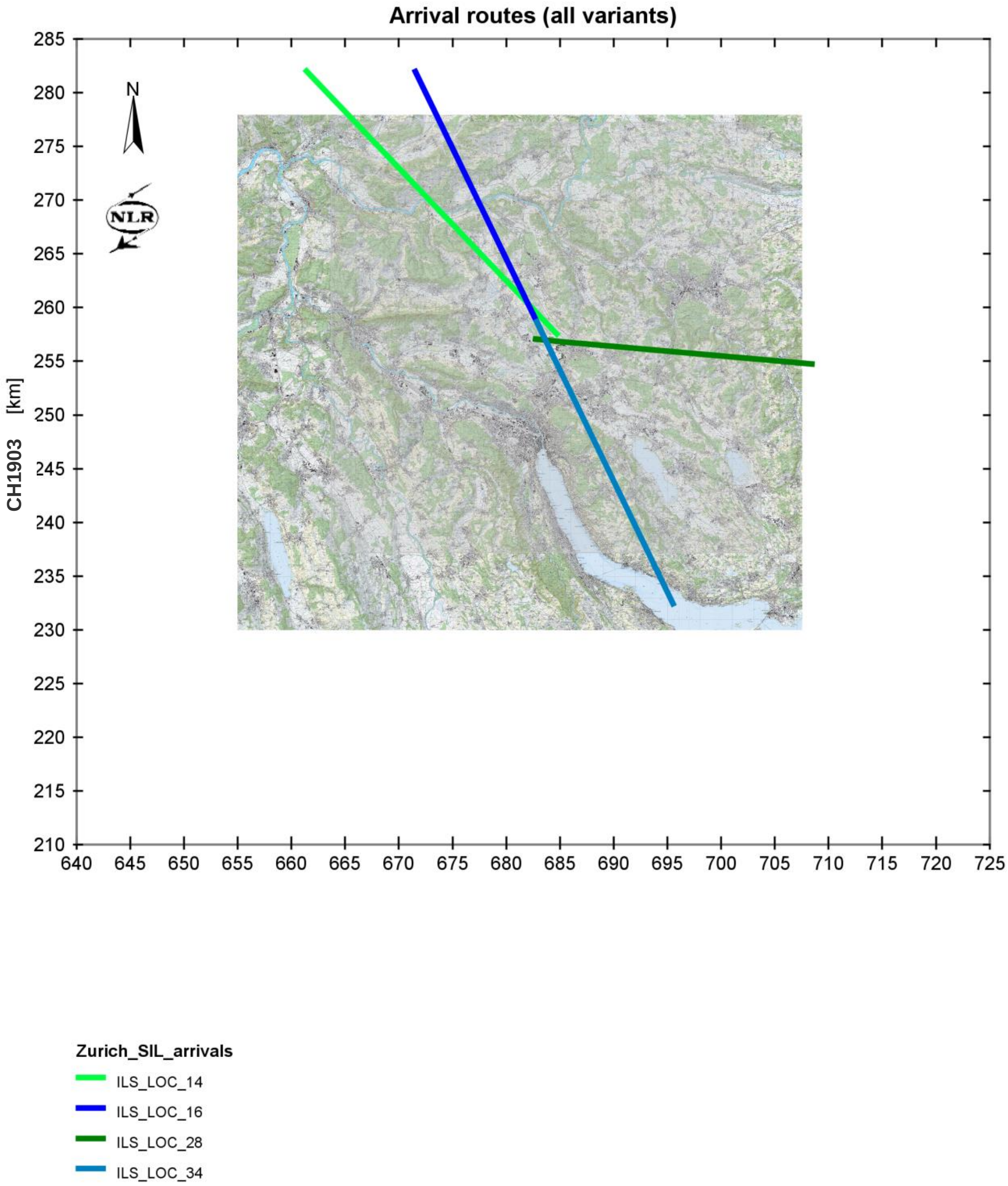

Figure C.1: Arrival routes for all variants

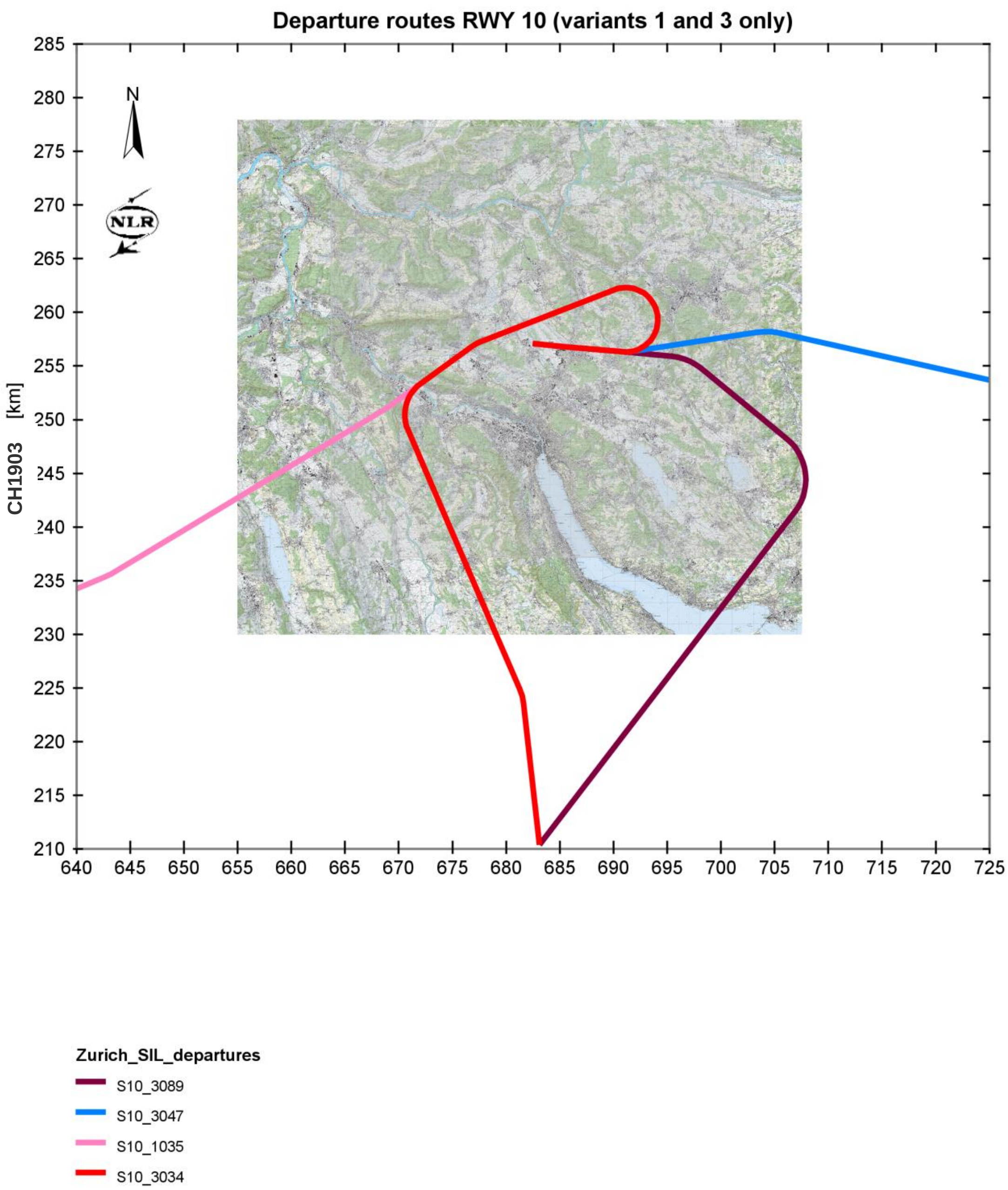

Figure C.2: Departure routes on RWY 10 for variant 1 and variant 3

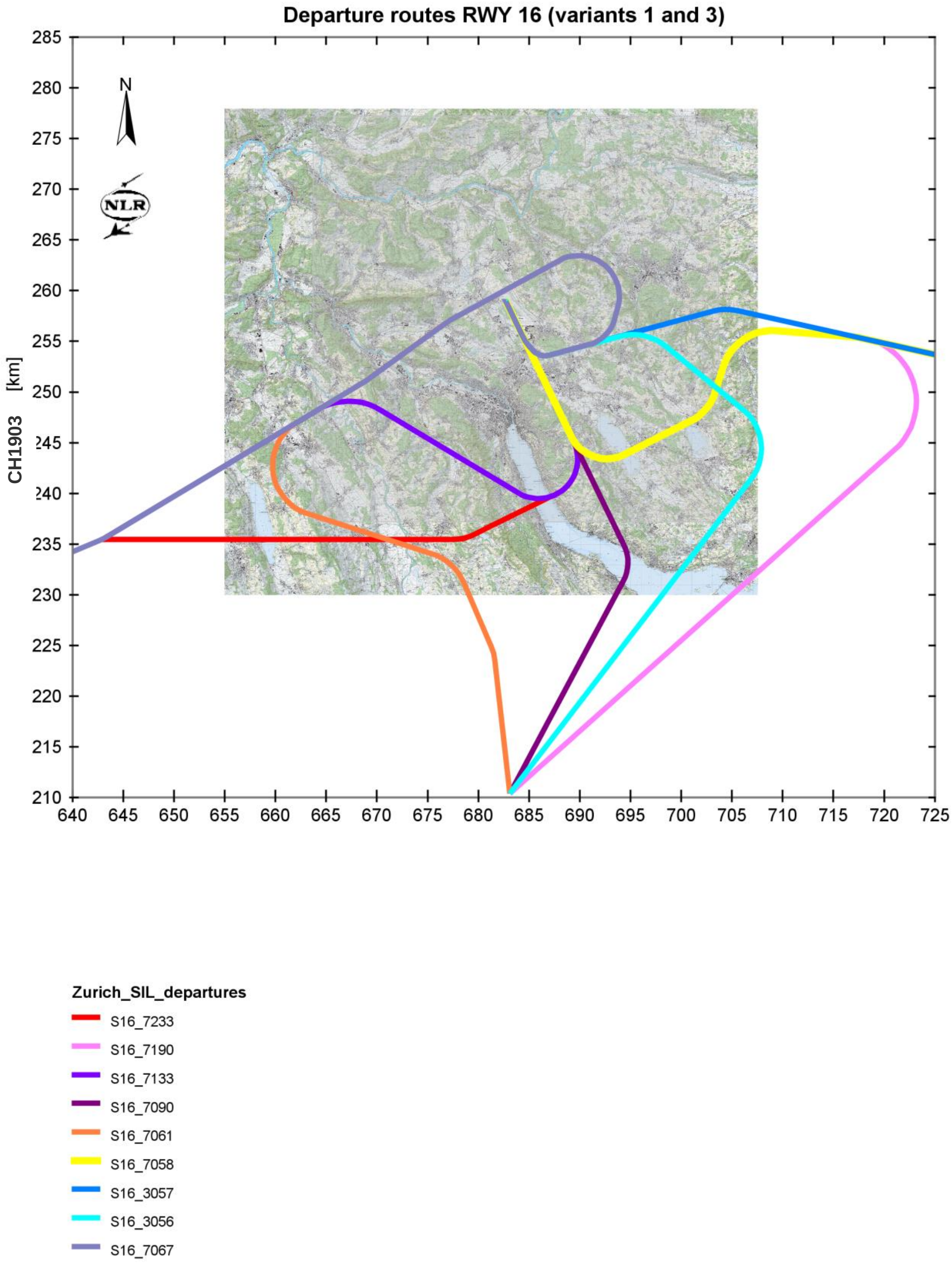

Figure C.3: Departure routes on RWY 16 for variant 1 and variant 3

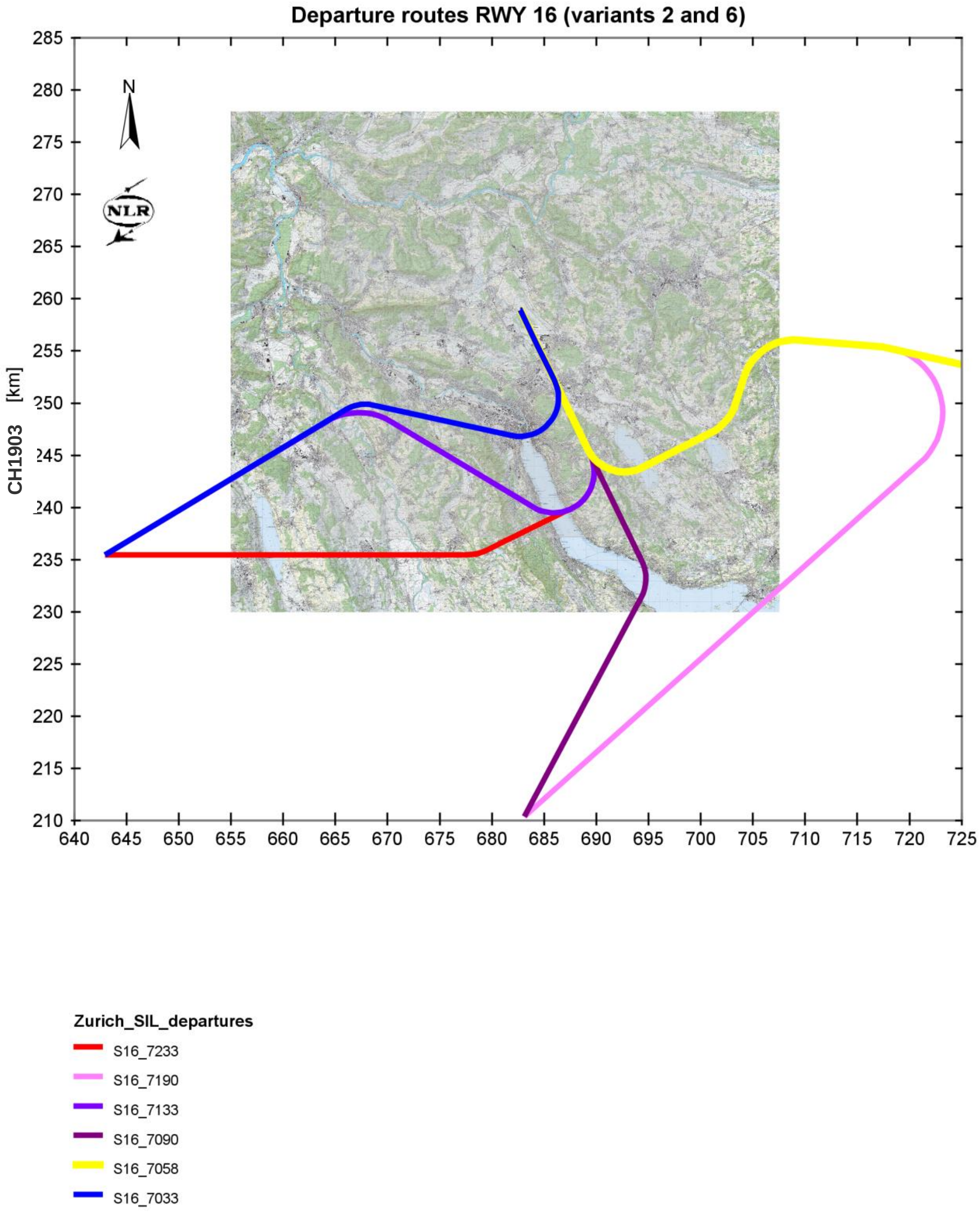

Figure C.4: Departure routes on RWY 16 for variant 2 and variant 6

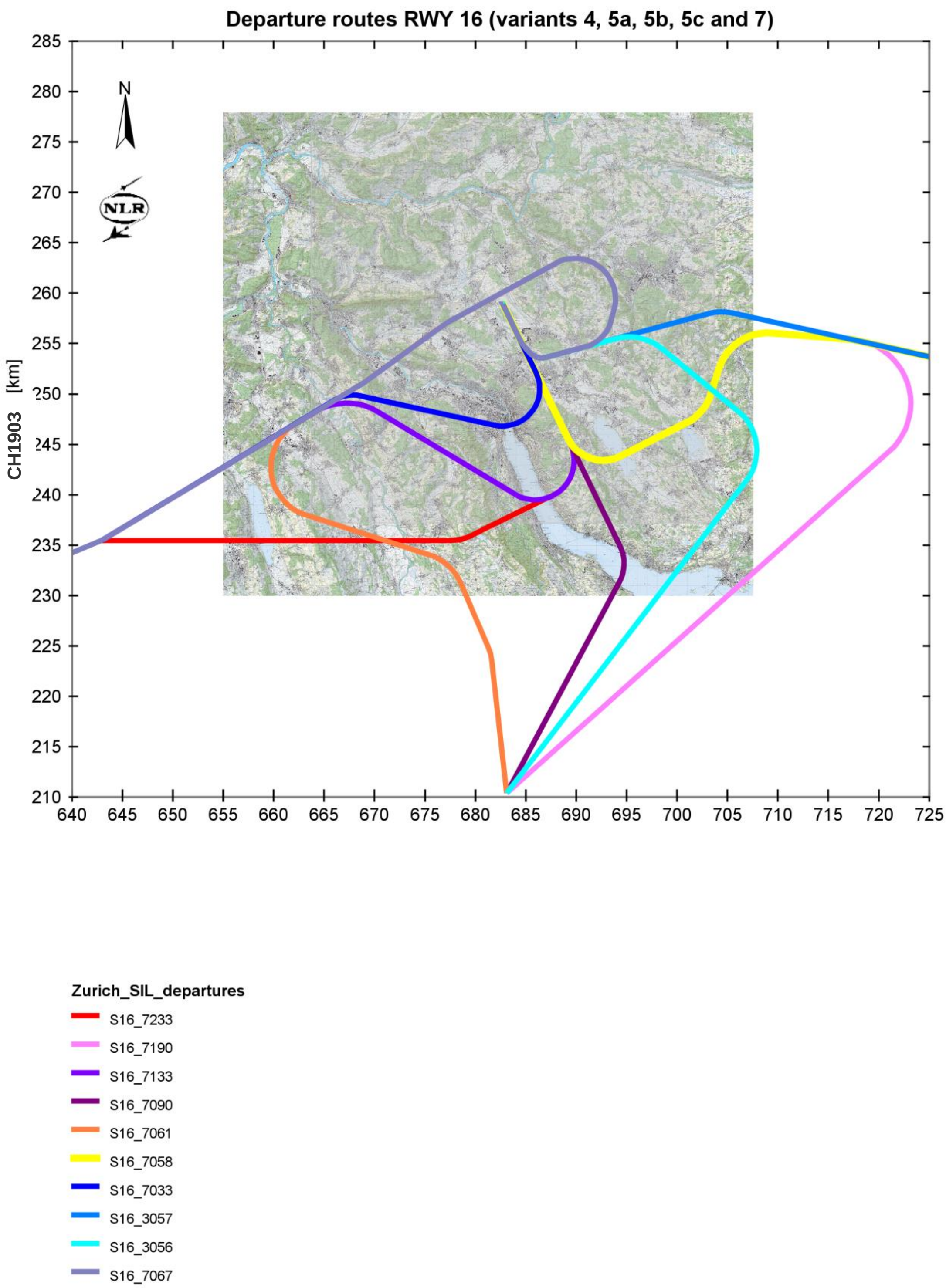

Figure C.5: Departure routes on RWY 16 for variant 4, variants 5a, 5b, 5c and variant 7

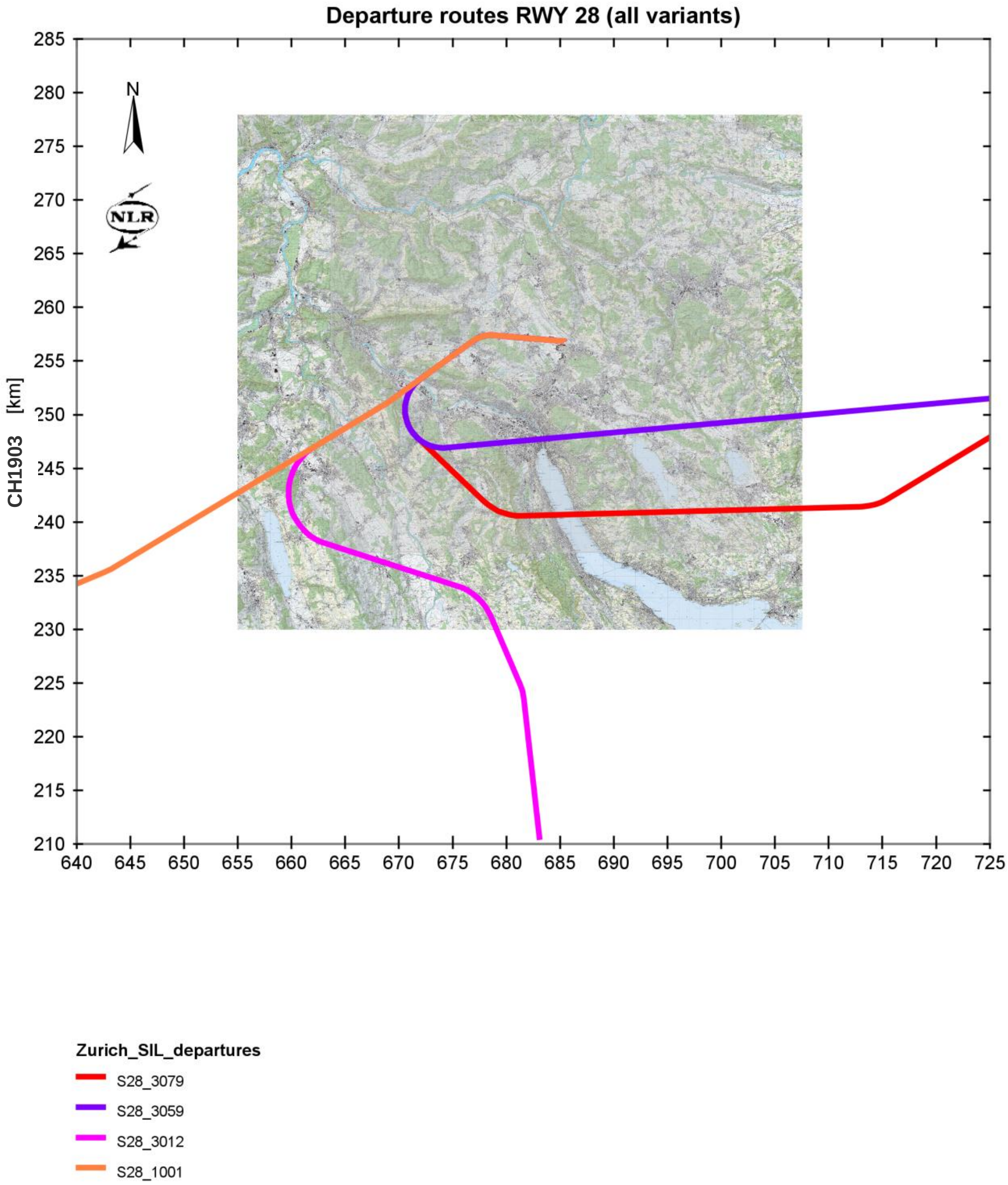

Figure C.6: Departure routes on RWY 28 for all variants

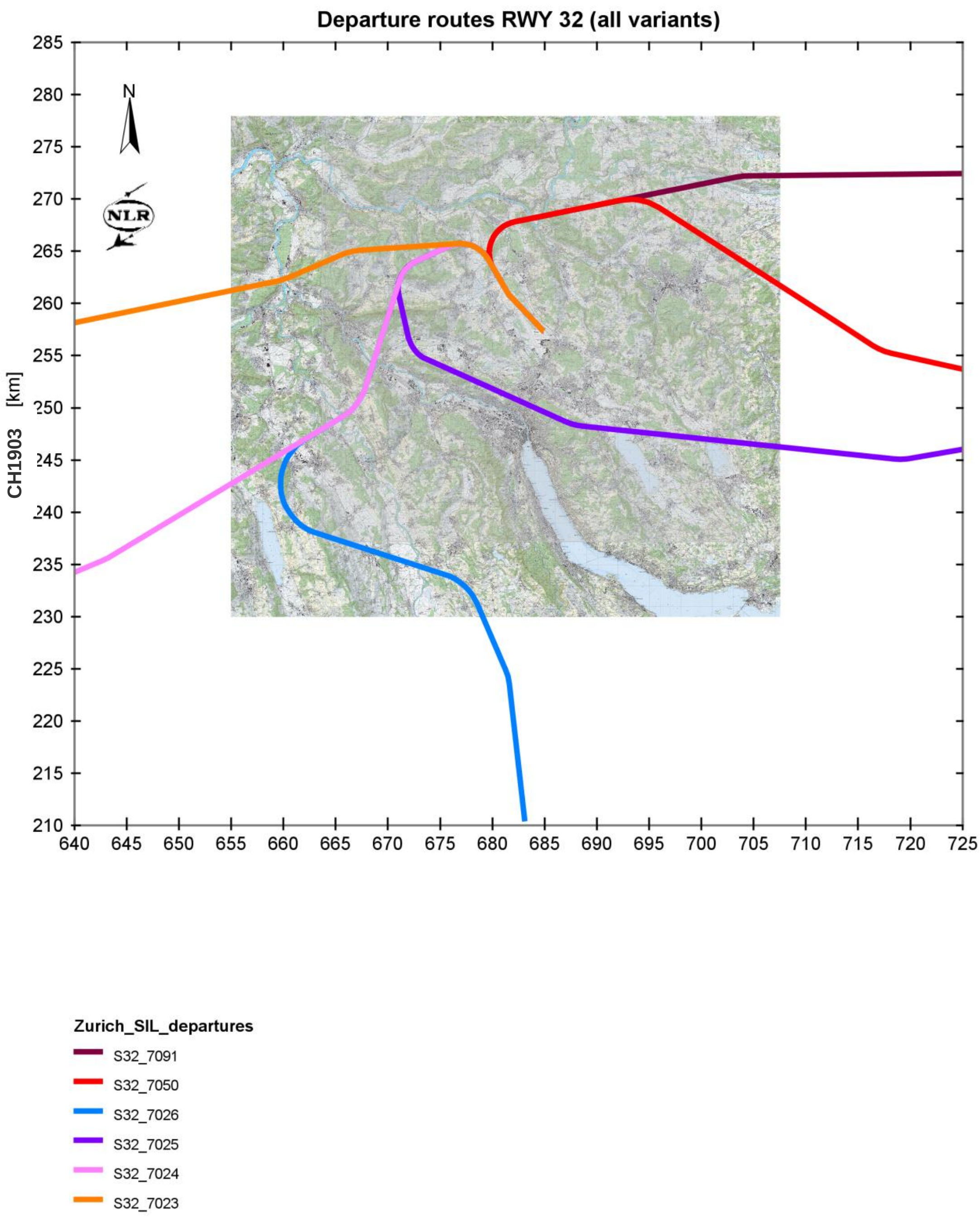

Figure C.7: Departure routes on RWY 32 for all variants

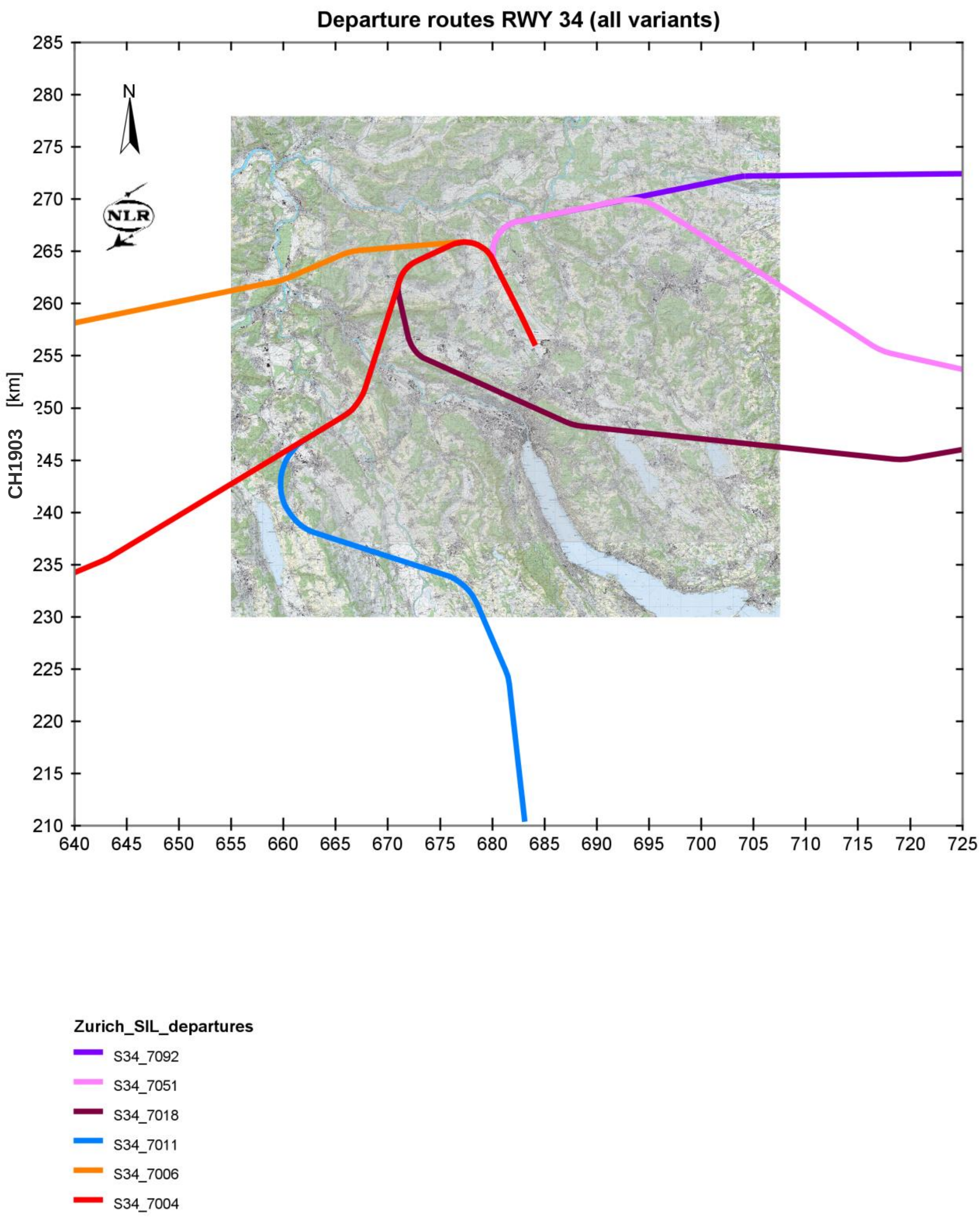

Figure C.8: Departure routes on RWY 34 for all variants

Appendix D List of aircraft types and MTOW

Table D.1: MTOWs for noise-representative aircraft types

Noise-representative A/C type	Weighted MTOW (metric tonnes)
A3103	171.826
A319	68.046
A320	78.000
A321	94.000
A3302	236.929
A3403	570.079
A3406	380.000
B73F	78.992
B73S	69.971
B73V	61.000
B7473	187.220
B7474	427.323
B7572	116.000
B7672	179.000
B7673	187.000
B7772	304.011
CL65	18.672
E145	28.097
FK10	46.000
FK70	50.816
MD11	283.360
RJ100	41.200
TU54M	57.225

Table D.2: MTOWs for detailed aircraft types and the groupings for noise-representative aircraft types

A/C-Type	NLR-corrected A/C-type	Percentage per WTC	WTC	Noise representative A/C-type	MTOW per NLR-corrected A/C –type (metric tonnes)
B773	B773	61.16%	Heavy	B7772	299.000
B772	B772	12.80%	Heavy	B7772	298.000
A332	A332	7.26%	Heavy	A3302	238.000
B77W	B77W	7.18%	Heavy	B7772	352.000
A333	A333	4.03%	Heavy	A3302	235.000
A346	A346	2.53%	Heavy	A3406	365.000
A388	A388	2.47%	Heavy	A3403	569.000
B77L	B77L	0.88%	Heavy	B7772	348.000
A306	A306	0.82%	Heavy	A3103	172.000
B748	B748	0.51%	Heavy	B7474	448.000
B744	B744	0.18%	Heavy	B7474	413.000
B74S	B74S	0.05%	Heavy	B7474	285.765
MD11	MD11	0.02%	Heavy	MD11	286.000
A310	A310	0.02%	Heavy	A3103	164.000
B763	B763	0.02%	Heavy	B7673	187.000
A342	A342	0.02%	Heavy	A3403	275.000
A124	A124	0.01%	Heavy	B7474	405.000
A345	A345	0.01%	Heavy	A3403	365.000
IL62	IL62	0.01%	Heavy	B7473	163.000
IL76	IL76	0.01%	Heavy	B7473	195.000
B762	B762	0.00%	Heavy	B7672	180.000
DC10	DC10	0.00%	Heavy	MD11	268.000
A320	A320	28.15%	Medium	A320	78.000
E190	E190	21.01%	Medium	FK70	55.000
A321	A321	17.34%	Medium	A321	93.000
A319	A319	8.95%	Medium	A319	77.000
C100	BCS1*	7.19%	Medium	A319	59.000
E195	E190	3.47%	Medium	FK70	55.000
B738	B738	2.77%	Medium	B73F	80.000
B737	B737	2.48%	Medium	B73S	78.000
DH8D	DH8D	1.94%	Medium	E145	30.000
SB20	SB20	1.82%	Medium	E145	23.000
CRJ9	CRJ9	1.29%	Medium	FK70	38.000
E170	E170	1.27%	Medium	FK70	41.000
AT72	AT72	0.47%	Medium	E145	23.000
F100	F100	0.45%	Medium	FK10	46.000
FA7X	FA7X	0.35%	Medium	E145	32.000
GLF5	GLF5	0.33%	Medium	E145	42.000
GLEX	GLEX	0.26%	Medium	E145	46.000
AT45	AT45	0.17%	Medium	E145	19.000
DH8C	DH8C	0.12%	Medium	E145	19.510
GL5T	GL5T	0.08%	Medium	E145	45.000
B739	B739	0.06%	Medium	B73F	86.000

A/C-Type	NLR-corrected A/C-type	Percentage per WTC	WTC	Noise representative A/C-type	MTOW per NLR-corrected A/C –type (metric tonnes)
AT43	AT43	0.02%	Medium	E145	18.000
A318	A318	0.01%	Medium	A319	68.000
B752	B752	0.01%	Medium	B7572	116.000
B732	B732	0.00%	Medium	B73S	53.000
E175	E170	0.00%	Medium	FK70	41.000
AN72	AN72	0.00%	Medium	TU54M	35.000
B462	B462	0.00%	Medium	RJ100	44.000
B734	B734	0.00%	Medium	B73F	69.000
GLF3	GLF3	0.00%	Medium	E145	32.000
A140	A140	0.00%	Medium	E145	21.500
AN12	AN12	0.00%	Medium	TU54M	64.000
B461	B461	0.00%	Medium	RJ100	38.000
C295	C295	0.00%	Medium	E145	24.000
T154	T154	0.00%	Medium	TU54M	90.000
B721	B721	0.00%	Medium	TU54M	77.000
YK42	YK42	0.00%	Medium	TU54M	58.000
B722	B722	0.00%	Medium	TU54M	90.000
B733	B733	0.00%	Medium	B73S	62.000
B735	B735	0.00%	Medium	B73V	61.000
F50	F50	0.00%	Medium	E145	21.000
CRJ7	CRJ7	18.37%	Small	CL65	34.000
C56X	C56X	13.65%	Small	CL65	10.000
CL60	CL60	10.48%	Small	CL65	22.000
H25B	H25B	8.21%	Small	CL65	13.000
F2TH	F2TH	5.43%	Small	CL65	20.000
C25A	C25A	5.30%	Small	CL65	7.000
E145	E145	5.13%	Small	CL65	22.000
C550	C550	4.56%	Small	CL65	7.000
F900	F900	3.51%	Small	CL65	23.000
GLF4	GLF4	3.43%	Small	CL65	34.000
C25B	C25B	3.15%	Small	CL65	7.000
E135	E135	2.86%	Small	CL65	24.000
CL30	CL30	2.11%	Small	CL65	18.000
C680	C680	1.83%	Small	CL65	20.000
E55P	E55P	1.74%	Small	CL65	9.000
J328	J328	1.23%	Small	CL65	16.000
B350	B350	1.16%	Small	CL65	7.000
C560	C560	1.14%	Small	CL65	10.000
C650	C650	0.92%	Small	CL65	11.000
SF34	SF34	0.85%	Small	CL65	14.000
CRJ2	CRJ2	0.84%	Small	CL65	25.000
GALX	GALX	0.68%	Small	CL65	17.000
C750	C750	0.60%	Small	CL65	17.000
FA50	FA50	0.42%	Small	CL65	19.000
C25C	C25C	0.36%	Small	CL65	5.000

A/C-Type	NLR-corrected A/C-type	Percentage per WTC	WTC	Noise representative A/C-type	MTOW per NLR-corrected A/C –type (metric tonnes)
HA4T	HA4T	0.36%	Small	CL65	18.000
G150	G150	0.34%	Small	CL65	12.000
LJ40	LJ40	0.31%	Small	CL65	10.000
SW4	SW4	0.22%	Small	CL65	8.000
C551	C551	0.20%	Small	CL65	7.000
D328	D328	0.18%	Small	CL65	14.000
ASTR	ASTR	0.10%	Small	CL65	12.000
H25C	H25C	0.08%	Small	CL65	15.000
B190	B190	0.06%	Small	CL65	8.000
SW3	SW3	0.06%	Small	CL65	6.000
E120	E120	0.04%	Small	CL65	13.000
JS32	JS32	0.03%	Small	CL65	7.350
D228	D228	0.03%	Small	CL65	7.000
AC95	AC95	0.02%	Small	CL65	4.680
FA20	FA20	0.01%	Small	CL65	14.000
L29B	L29B	0.01%	Small	CL65	19.051

*) The aircraft type is the new Bombardier CS 100.

Appendix E Movements per variant

Table E.1: Number of departures per runway and per variant

RWY	V1	V2	V3	V4	V5a	V5b	V5c	V6	V7
10	6111		6111						
14									
16	28652	132837	28695	34859	34855	66304	36617	35183	23633
28	100220	2528	100220	100220	102195	72387	102195	102863	80150
32	33830	37092	33830	33830	34110	34110	34110	34800	61792
34	5205	6459	5205	5205	5244	5244	5244	5336	8633
Total	174018	178916	174061	174114	176404	178045	178166	178182	174208

Table E.2: Number of arrivals per runway and per variant

RWY	V1	V2	V3	V4	V5a	V5b	V5c	V6	V7
10									
14	121401	124367	121401	121401	123926	123833	123926	125448	92202
16	2478	2538	2478	2478	2529	2527	2529	2560	1882
28	33661	34411	33661	33661	34639	34639	34639	34435	64116
32									
34	16503	16849	16503	16503	16468	16468	16468	16521	16220
Total	174043	178165	174043	174043	177562	177467	177562	178964	174420

Appendix F Identification of risk calculation

Each risk calculation, individual risk or societal risk, is registered with a calculation number. The identifications for the calculations carried out for SIL Zürich variants are shown in Table F.1.

Table F.1: Identification numbers for the risk calculations

NLR project number: 2494117	
Calculation identification number	**SIL Zürich variant**
14040101	Variant 1
14040102	Variant 2
14040103	Variant 3
14040104	Variant 4
14040105	Variant 5a
14040106	Variant 5b
14040107	Variant 5c
14040108	Variant 6
14040109	Variant 7

WHAT IS NLR?

The NLR is a Dutch organisation that identifies, develops and applies high-tech knowledge in the aerospace sector. The NLR's activities are socially relevant, market-orientated, and conducted not-for-profit. In this, the NLR serves to bolster the government's innovative capabilities, while also promoting the innovative and competitive capacities of its partner companies.

The NLR, renowned for its leading expertise, professional approach and independent consultancy, is staffed by client-orientated personnel who are not only highly skilled and educated, but also continuously strive to develop and improve their competencies. The NLR moreover possesses an impressive array of high quality research facilities.

***NLR** – Dedicated to innovation in aerospace* www.nlr.nl