Assessment of aircraft accident probability on industrial facilities by means of GIS Risk-Register, the examples of Geneva, "Geneva Risk"
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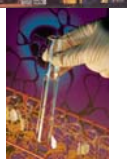

Alberto Susini
Geneva, CH
alberto.susini@etat.ge.ch

AIG-Geneva
GFL-Berlin
Basler&Hofmann-Zürich

Assessment of aircraft accident probability on industrial facilities by means of GIS Risk-Register, the examples of Geneva, "Geneva Risk"

Alberto Susini[1], Andreas Schönenberger [2], Christian Hürzeler [2], Norbert Knechtle[2], Alexandre Massot [3], Hartmut Fricke [4], Norbert Gronak [4], Christoph Thiel [4], Daniel Fiedler [4]

[1] Geneva Labor Inspectorate, Environmental Affairs (OCIRT), Canton of Geneva

[2] Basler & Hofmann, Consulting Engineers Ltd., Zurich

[3] Geomatic Competence Center (GCC), Canton of Geneva

[4] Gesellschaft für Luftverkehrsforschung GmbH (GfL), Berlin,

Objective of the project

- The goals of the project were to evaluate how the risks for different types of industry, in particular those dealing with dangerous chemicals, may increase due to aircraft operations inside the area of the canton of Geneva
- This evaluation would then permit the setting up of priorities in monitoring installations and further enhance land-use practices and the preparedness of emergency response planning

These objectives were achieved by :

- Performing a new complete risk assessment of the airport
- Adapting calculations and risk mapping production of an existing risk register of major hazard facilties of the Geneva canton
- Putting together by ICT the results and try to see if the airport air trafic risk has an influence of the existing industrial risk level of major hazard facilities

Historical background on risks around the airport

- Risk assesments in CH/EU should take also in account the consequences of events like the low probabilities of an aircraft crash onto an industrial site
- Until recently, only generic aircraft crash probabilities were calculated for the entire area over Switzerland with values expressed as the probability per year and square meter for both accidents during the en-route and the approach flight phase
- This was seen as not sufficient with regard to worldwide aviation accident data of the last decades showing different aircraft crash statistics
- A serious attempt to systematize the data processing of aircraft accident into hazardous facilities was made in 1996 by the US Department of Energy (DOE)

Calculated risks around the airport

- The airport with the cantonal and federal authorities decided to complile an electronic map of individual and collective (societal) risks around the airport
- The individual risk is the probability that someone at a specific location dies due an aircraft accident
- The societal risk is the probability of a given number of deaths in particular regions along the aircraft departure or arrival route: these regions are locally referred to as individual segments
- These new and more precise probability and risk results were transformed into aircraft accident probabilities per hectare

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Calculated risks around the airport

- The study conducted by GfL refers to the operational situation at Geneva airport in 2005, during which there were 170.824 air traffic movements
- The analyses give a risk assessment posed by the commercial Instrument Flight Rules (IFR) traffic only (151.937), plus a second one including additional flight operations following Visual Flight Rules (VFR)
- The study methodology is based on probabilistic aircraft crash rates modelling and Flight procedure analyses

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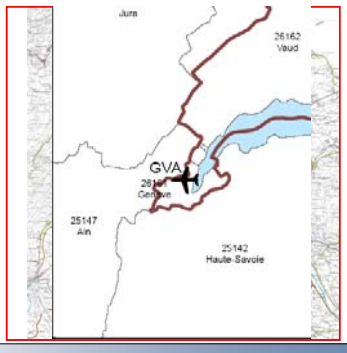
Investigation Area

- The selected investigation area covers a square of 40 x 40 km, and is centred on the Airport Reference Point (ARP) – slightly cut on the western side
- The investigation area is virtually divided into a set of grids, each with a size of 100 × 100 m²



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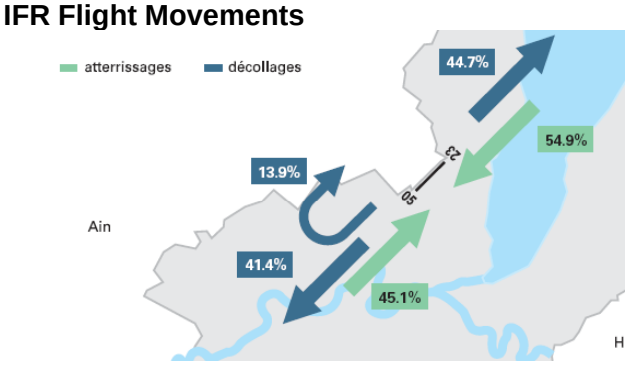
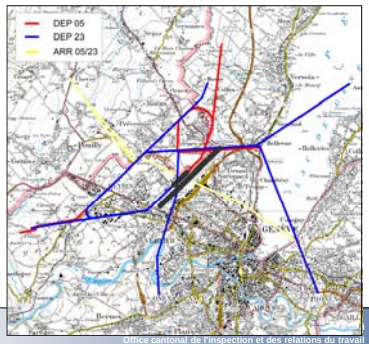
IFR Flight Movements



Structure of VFR Routes

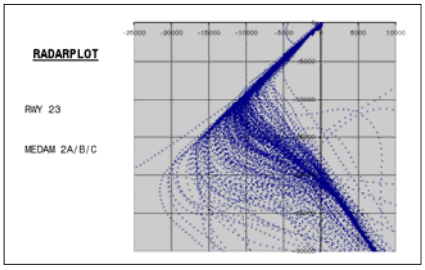
Traffic distribution:
equally
on all VFR-Routes

VFR Helicopter traffic not considered

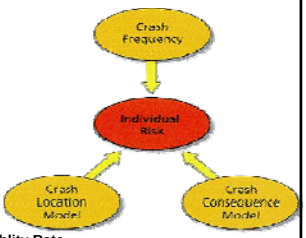


Departure Route Analysis – Applied Methodology

- Example Radarplots for MEDAM 2A/B/C
- 809 out of 6.456 IFR-Departures used for statistical analysis



Model Structure



Three modules developped by GFL form the External Risk Assessment Model:

- **1. Accident Ratio, AR**
  Determination of the local Accident Probablity Rate
- **2. Accident Location, AL**
  Determination of the local distribution of accidents
- **3. Accident Consequence, AC**
  Determination of the local impact of accidents:

Accident Ratio Model

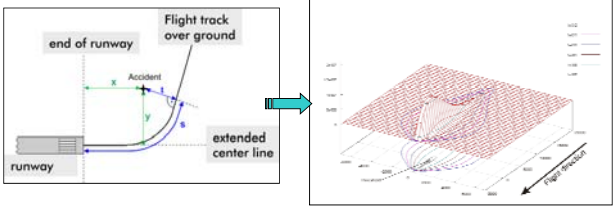
- Traffic Accident Investigation for all 62 airports in a predefined timescale of 15 years using world wide Accident Databases

case	IFR Accident Rate per operation
Reference Scenario 2005	**1,52 x 10^{-7}**
Forecast 2020	***5,21 x 10^{-8}***

Accident Ratio - VFR	MTOW	
	< 2,0 t	2 to 5,7 t
AR_{VFR} [per movement]	**4,46 x 10^{-6}**	**8,04 x 10^{-6}**

Accident Location Model

- Sample of modeled AL probablity density function (PDF)
- AL along the mean trajectory fit with a Weibull PDF
- AL across the mean trajectory fit with a Laplace PDF



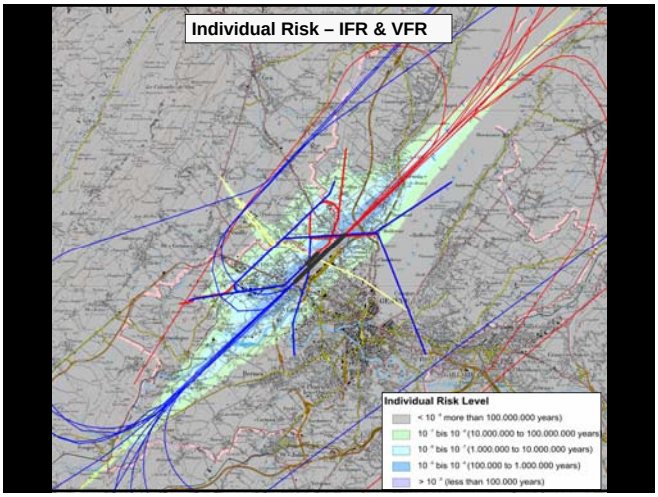
- Example: landing density function

Impact Area: up 20 km away from the runway

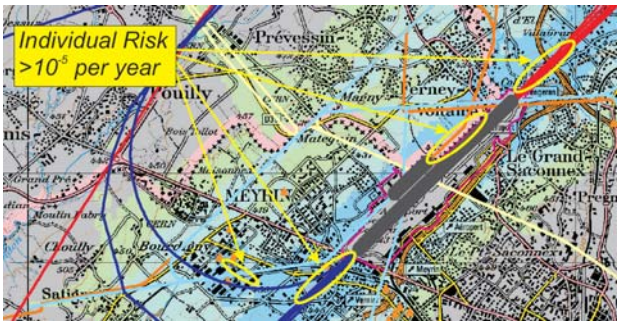
Accident Consequence Model (1)

Determination of the Accident Consequence (AC):
- has been scaled based on historical accident reports
- size of the consequence area depends on the aircraft mass and the type of terrain (open or cropped)
- Mortality (defined as the ratio of the number of third party fatalities in relation to the total number of people present in the Consequence Area) is modelled with a 60 % ratio

Derived Primary Accident Consequence Area			
Type of Topography	Area Size to Aircraft Mass Ratio	Resulting Radius for a 20 t aircraft	Resulting Radius for a 100 t aircraft
Open Terrain	**290 m^2/t**	43,0 m	96,1 m
Cropped Terrain	**180 m^2/t**	33,9 m	75,7 m



IR – IFR & VFR: Hot Spots



Societal Risk Model (1)

Determination of societal risk:

- a special formula is being applied to determine the societal risk for the present study according to OCIRT requirements

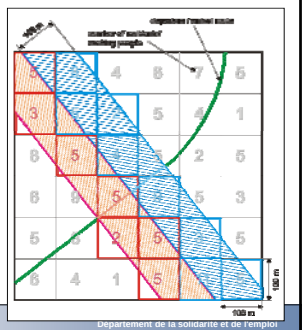
$$SR_{local}(x,y) = \sum P_i \times C_i$$

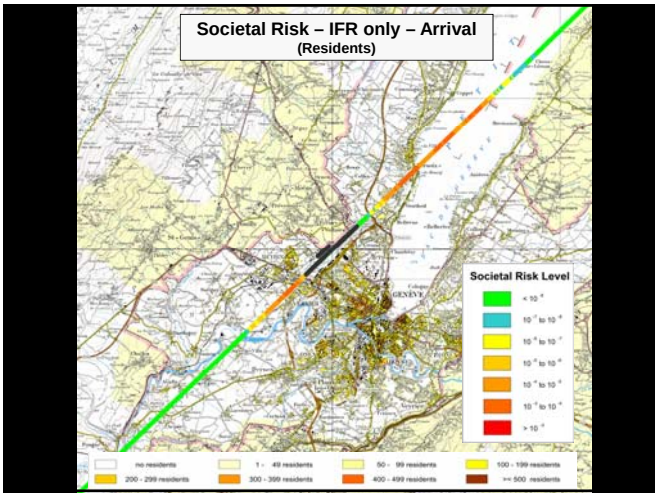
for each cell *i* inside the considered sector

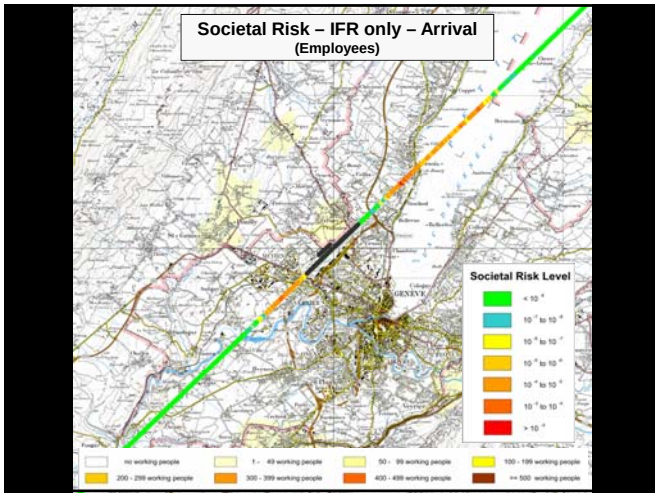
- aiming at linking the risk to individual departure or arrival routes thus allowing a geographical presentation of the results
- Twofold consideration of affected residents and employees

Societal Risk Model (2)

- societal risk is so calculated for each segment (segment length 100m) of a selected departure or arrival route
- all cells locating normal to a given segment will be considered for the risk on that segment
- societal risk for each route segment finally comes to the sum of all the risk of all considered cells







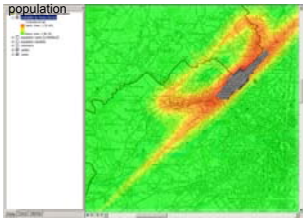
Integration of Airport risks in the risk register :

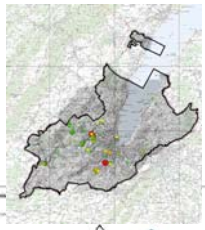
- STEP 1 Geneva airport risk mapping project (09.2006 to 11.2007) :
  - Global study of the Geneva airport air trafic on individual and collective risks
  - Transformation of the global results in an hectometric raster of aircrash frequency
- STEP 2 Integration of the hectometric aircrash frequency in the risk register :
  - Integration of the aircrash frequency in the informatic calculation model
  - Calculation of the aircrash damage (maximum release of the stored chemical substance)
  - Calculation of the new aircraft risk on the facility

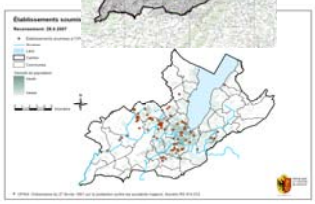
Integration of of the hectare raster of aircrash probability in the cantonal risk register (CRR)

The CRR is used to manage the risk calculation data of industrial facilities

Numerical models were defined and applied to the release and dispersion calculations for a range of sources of risk for the population







Risk calculations hypothesis (generalization and simplification)

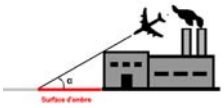
The specific risk linked to an aircraft accident on a particular entity inside an industrial site is defined as the product of the maximized damage multiplied by the probability per square hectometre of that accident.

For an aircrash on a facility, we consider that the maxmized damage is the released total amount of the stored quantities of chemical substances.

Where, inside an entity, there are different substances that undergo risk calculations, the risk to the entity as a whole is the sum of all of these different risks.

To show if the risk due to aircraft operations has any impact, we have to compare the effects of a maximized site damage due to an aircraft accident per hectare with the latent site risk independent of air traffic operations (e.g. that due to human error scenario, design failure, corrosion, etc.).

The comparison will so allow to figure out whether there is an influence linked to air traffic.



Aircrash on a building inside a facility

The surface of a builing where there is stored chemical is not always equivalent to an hectometer, we had to correct Hhecto with a building factor fb for obtaining the probability of occurrence Hocc.

The factor fb is equivalent to the surface of the builing including the "shadow surface" of the building.

Therefore the probability of occurrence is estimated in the following manner :

$Hocc = Hhecto \cdot fb$

Hocc **Probability of occurrence [1/year]**
Hhecto **Probability of hectometric aircrash [1/(year * ha)]**
fb **surface factor of the building [ha]**

The hectometric aircrash probability for a given facility Hhecto**, is estimated in the RCat by superposition of the hectometric grid with the exact topographic location of the facility**

Calculation of the risk in the case of an aircraft accident

The total risk for an industrial site, comprising a significant number of entities present in the site, is considered to be the sum of all risks of the substance scenarios (leakage of vessel release) of all the entities associated to this site added to all the aircraft accident risks of all the substances of all the entities.

Calculations of this risk for all the hazardous industrial facilities present in the CRR allow us to identify the cases where the risks due to an aircraft accident are predominant over the classical industrial risks.

Calculation of the accident scenario risk of the substance $R_{Sc\_SUBSTANCE}$ and the aircraft accident induced risk of the substance $R_{AC\_SUBSTANCE}$

$R_{Sc\_SUBSTANCE} = C_{Sc\_SUBSTANCE} \times P_{Sc}$ $R_{AC\_SUBSTANCE} = C_{Sc\_SUBSTANCE} \times P_{AC}$	$C_{Sc\_SUBSTANCE}$: Damage linked to the substance P_{Sc} : Probability of the scenario accident P_{AC} : Probability of the aircraft accident on the entity

Calculation of the total risk of the substance (accident scenario and air crash) $R_{TOT\_SUBSTANCE}$

$R_{TOT\_SUBSTANCE} = R_{Sc\_SUBSTANCE} + R_{AC\_SUBSTANCE}$	$R_{Sc\_SUBSTANCE}$: Risk scenario of the substance $R_{AC\_SUBSTANCE}$: Risk aircraft accident of the substance

Calculation of the risk of an accident scenario and of an aircraft accident on the entity

$R_{Sc\_entity} = \Sigma [R_{Sc\_substance}]$
$R_{AC\_entity} = \Sigma [R_{AC\_substance}]$

Calculation of the total risk of an entity (scenario and air crash) R_{TOT_Enity}

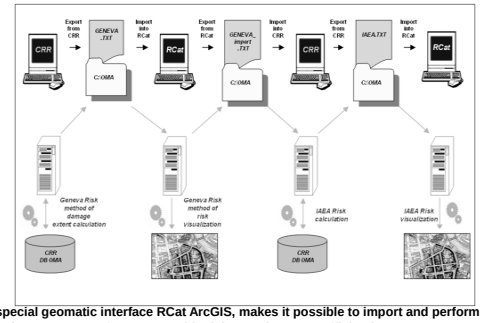
$R_{Tot\_entity} = [R_{Sc\_entity}] + [R_{AC\_entity}]$

Calculation of the risk linked to the site

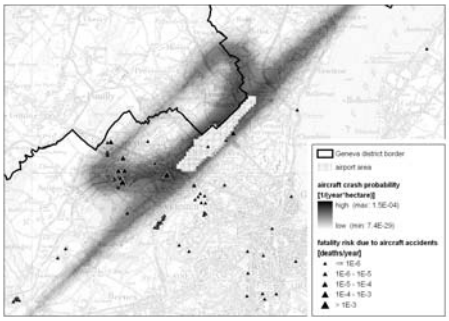
$R_{Sc\_SITE} = \Sigma [R_{Sc\_entity}]$
$R_{AC\_SITE} = \Sigma [R_{AC\_entity}]$

Calculation of the total risk of the industrial site

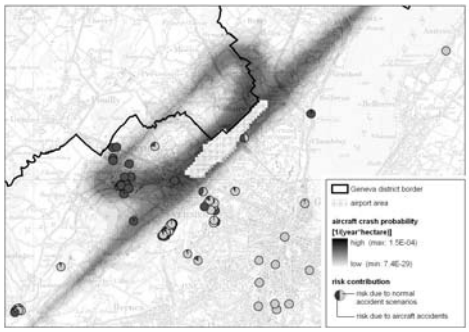
$R_{Tot\_SITE} = [R_{Sc\_SITE}] + [R_{AC\_SITE}]$



- A special geomatic interface RCat ArcGIS, makes it possible to import and perform calculations necessary for cartographic risk mapping more efficiently.
- File exchange between the CRR and the RCat for calculations and map visualizations were implemented.
- To integrate the aircraft risk calculations, it was necessary to adapt the CRR Oracle database to be the RCat interface.



Potential risk of plants due to aircraft accidents (fictive results)



Risk contribution (risk due to aircraft accidents in comparison to risk due to normal accident scenarios) (fictive results)

Result of aircrash into major hazardous faclities