Model-Based Prediction of Incident and Accident Probabilities

Ideas Beyond Dividing the Number of Accidents by the Number of Flights

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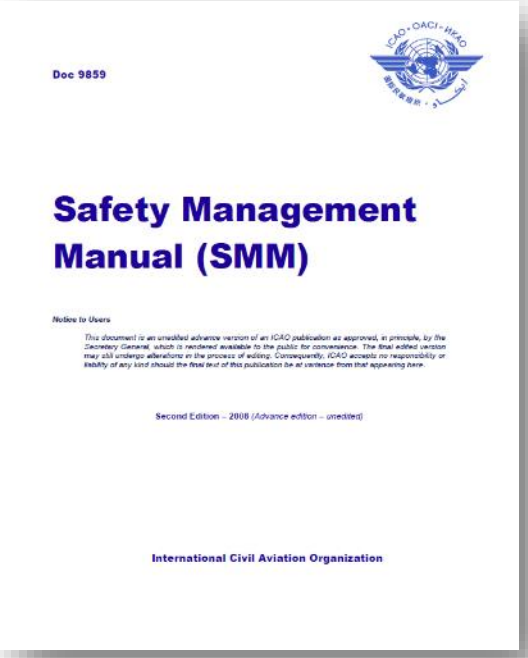
International Civil Aviation Organization (ICAO) – DOC 9859

In 2008, ICAO introduced ICAO DOC 9859 whose objective is to provide guidance on safe management. Airlines are required to implement a safety management system and to define their own **Acceptable Level of Safety (ALoS).**


Doc 9859

Safety Management Manual (SMM)

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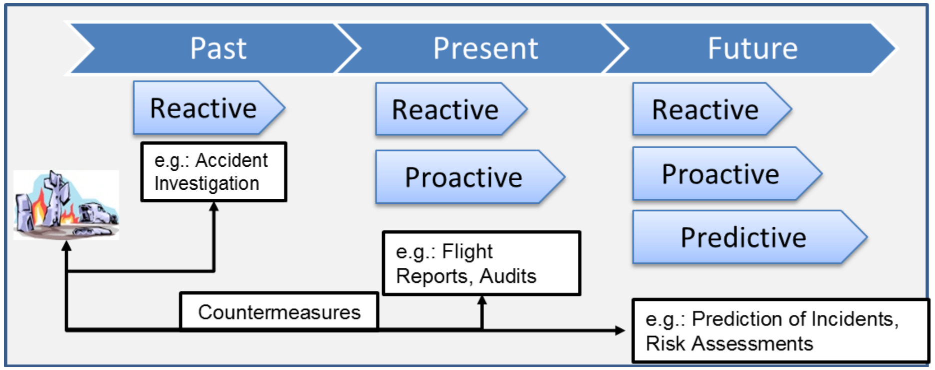
Second Edition – 2008 (*Advance edition – unedited*)

International Civil Aviation Organization

<u>Definition of ALoS within DOC 9859:</u>

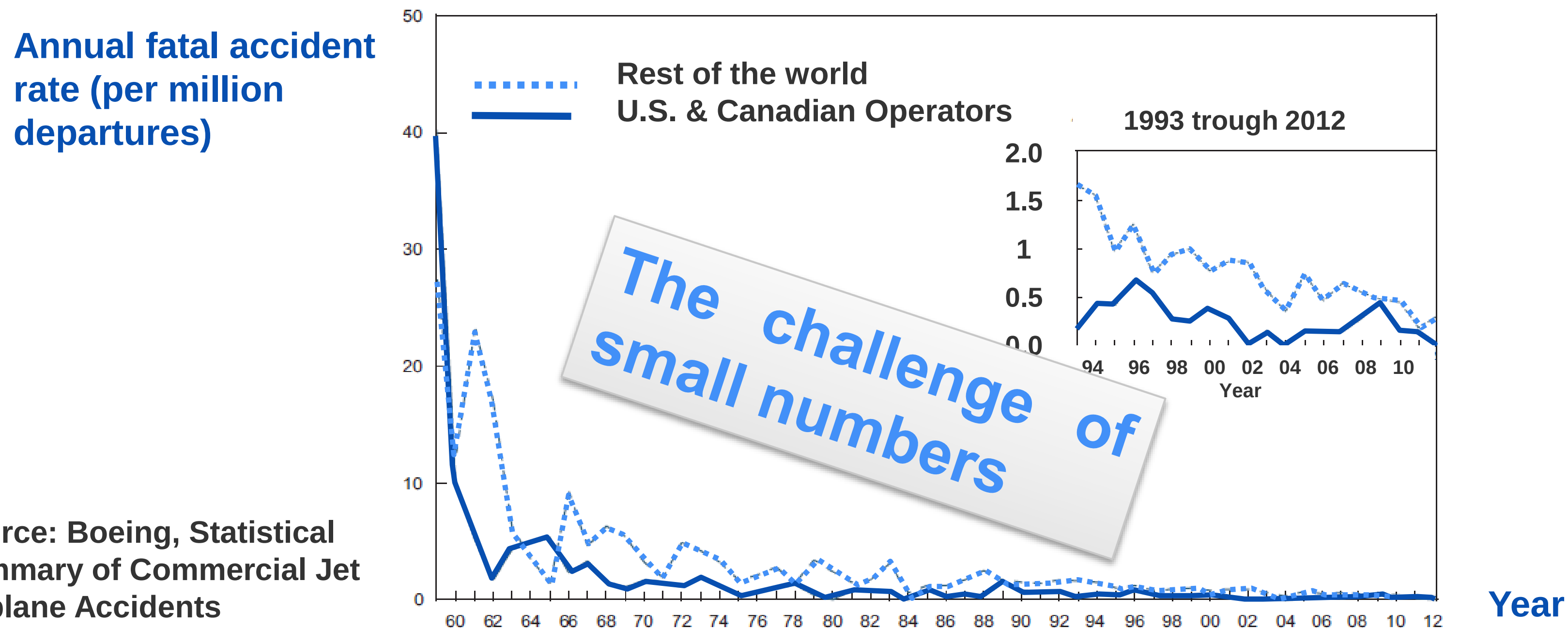
The acceptable level of safety performance (…) is a manifestation of **what the State considers as appropriate** within the context of its own aviation system.

Europe's vision in Flightpath 2050 (FP2050) sets a **target accident rate** of less than one accident per ten million commercial flights (i.e. **10^{-7} accidents per flight**).



Adopted from Lufthansa

How do we measure the safety level of a single airline?



Source: Boeing, Statistical Summary of Commercial Jet Airplane Accidents

- How do you measure safety for a **single** airline?
- Which safety metrics are appropriate?
- How do you determine **your airline's most likely accident**?
- How can you quantify the effectiveness of risk mitigation measures **before** implementing them?
- Can you **predict the occurrence of incidents** and act proactively in order to reduce the risks of incidents within your airline?

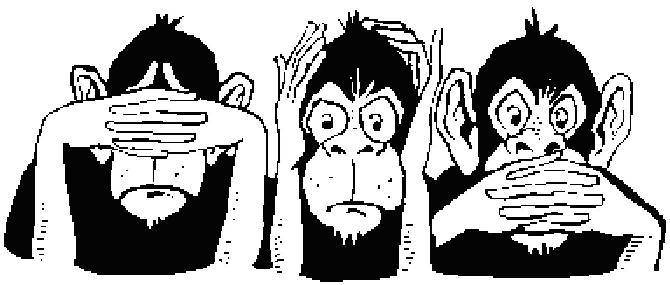
Individual incident probabilities of a single airline

The occurrence probability for a serious incident using a statistical approach:

$$P_{\text{Incident}} = \frac{Frequency\ of\ Incident^{*}}{Number\ of\ Flights}$$

Runway Overrun Example: $P_{\text{Overrun}} = \frac{0}{400\,000} = 0\%$

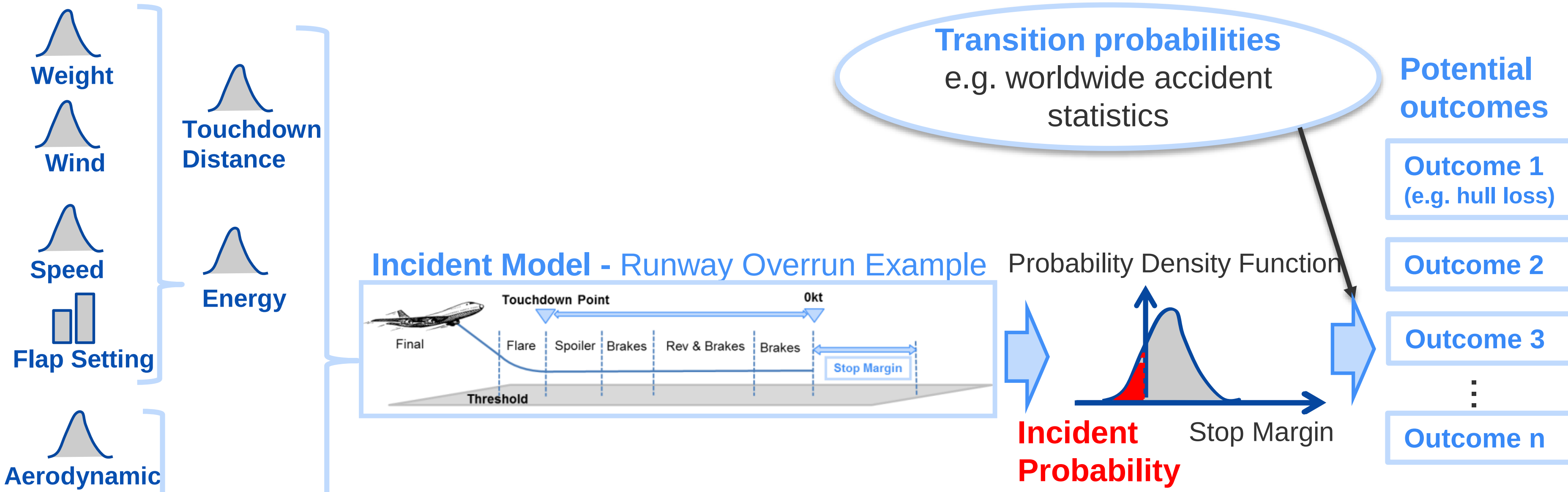
VS.

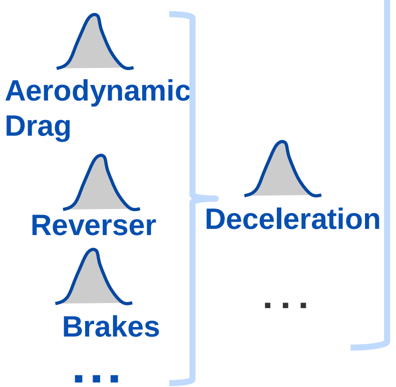


A simple statistical approach is in inappropriate and **unsuitable for rare events,** such as accidents or serious incidents, whose occurrence probabilities within a single airline are small (**10^{-x}**).

*__Serious incidents__ as defined in ICAO Annex 13

Combining the probability distributions of contributing factors





Contributing factors

Hypothesis

Conventionally, it was not possible to make statistically valid statements regarding certain accident or serious incident probabilities **for a single airline**, if the airline is fortunate enough to never or only infrequently experience many types of accidents and/or incidents.

However, we hypothesize **that the factors that contribute to such events can be observed during normal flight operation**.

By **combining those contributing factors**, we are able to make statistically valid statements about the occurrence probability.

Statistical evaluation – identifying distribution types

Contributing Factors

Recorded (QAR)

Measured & Derived
- Approach speed deviation
- Touchdown (TD) distance (THR to TD)
- Start of braking
- ...

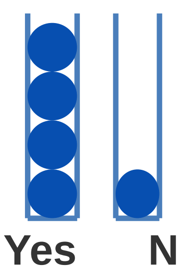
Not-Recorded / Not-Measured

Parameter Estimation (QAR)
- Friction coefficient
- Aerodynamic parameters
- …

Others (Database)
- Airport data
    - Runway length
    - ...
- Base of Aircraft Data (BADA)
- …

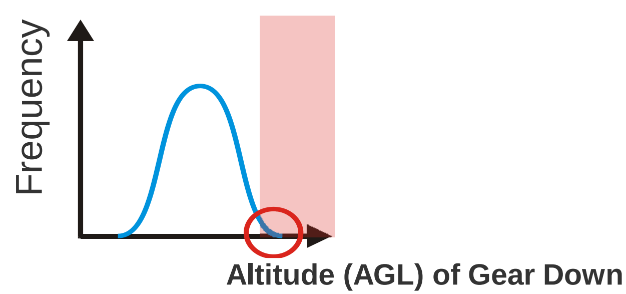
Probabilistic Approach: Modelling contributing factors as distributions (if applicable)

Gear Down at 2000ft AGL?



VS.

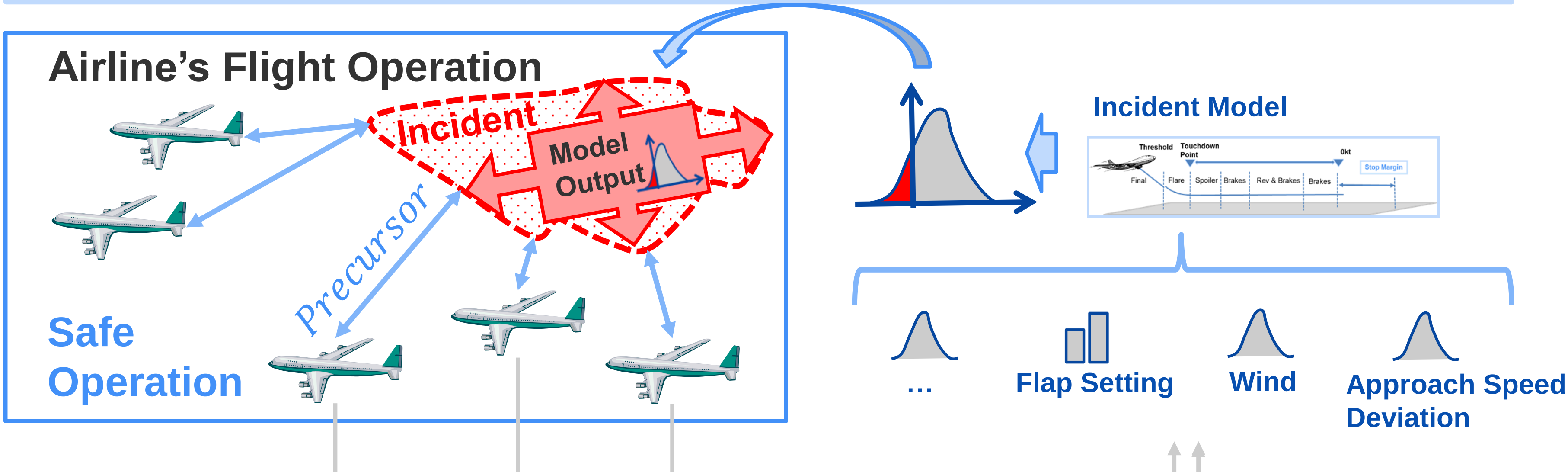
AGL at Gear Down ?



- Quality of statistical statements depend on how you look at the data.

Comparison between precursor and model-based predictions

FDM-Precursors for incidents and model-based prediction of incidents **complement** each other and enhance the understanding of potential risks.



Fitting distributions to the contributing factors.

FDM precursors

- quantify the **closeness** to an incident of a single flight
- detect potentially unsafe situations

Model-based predictions

- quantify the **probability** (area) of incidents within the flight operation
- based on the statistics of a flight operation of a single airline
- does **NOT** quantify the probability of an incident for **single flight**

Identifying the main driver and relevant postholder

Wind

Postholder	ENV
Controllable	No
…	…

Flap Setting

Postholder	TRA
Controllable	Yes
…	…

Approach Speed Deviation

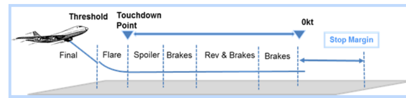
Postholder	TRA
Controllable	Yes
……	…

…

Postholder	…
Controllable	…
……	…

Propagating the probability distributions of the contributing factors through incident models allows us to compute their **sensitivities**.

Incident Model



	Human (HUM)				Maintenance (MAN)				Operations (OPS)			
	Training	Selection	Fatigue	…	Inspection Interval	Scheduled Maintenance	Age of Equipment	…	Planning	Ground OPS	ATC	
A/C Type 1												
A/C Type 2												
A/C Type 3												
A/C Type 4	1,000	[illegible]	1,824	0,380	0,917	0,137	0,684	1,243	[illegible]	0,841	1,234	[illegible]
A/C Type 5	0,508	0,351	0,949	0,269	0,704	1,101	0,600	[illegible]	1,289	[illegible]	[illegible]	[illegible]
A/C Type 6	0,516	0,122	0,705	0,270	0,231	0,691	0,291	0,542	0,249	0,508	0,322	[illegible]
A/C Type 7												

Hypothetical Values

- Tag each contributing factor with meta information
- The main drivers of the contributing factors leading to incidents can be identified and quantified

Change management

Contributing Factor	ENV	TRA	FOPS
Headwind	✓	✓	
Landing weight			✓
QNH	✓		
Temperature	✓		
VAPP deviation	✓	✓	
Spoiler deployed	✓		
Start of braking		✓	
Reverser deployment		✓	
…	…	…	…

Sensitivities of each contributing factor

Airbus A346*	
EDDM	All airports
0.50	0.37
0.05	0.07
0.05	0.00
0.17	0.02
0.13	0.14
0.01	0.00
0.80	0.79
0.06	0.05
…	…

Postholders' sensitivities

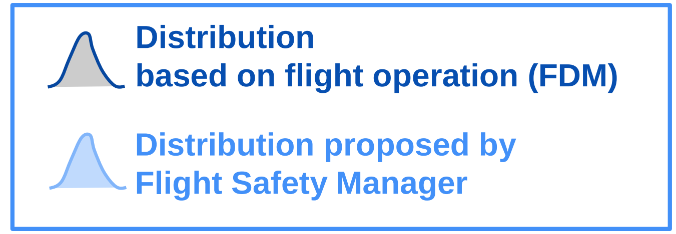
Aircraft*	ENV	TRA	FOPS
A320	0.57	1.34	0.08
A343	0.63	1.46	0.08
A346	0.58	1.37	0.06

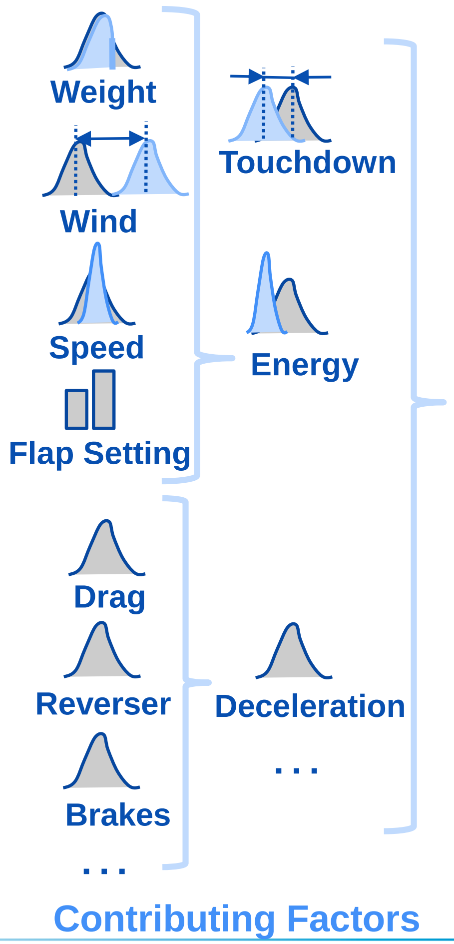
- **Identification of the driving factors**: The greater the absolute value, the higher the impact on the incident
- By summing up the sensitivities, we can determine the contribution of a postholder to the incident probability

*Preliminary results based on partially artificial FDM data

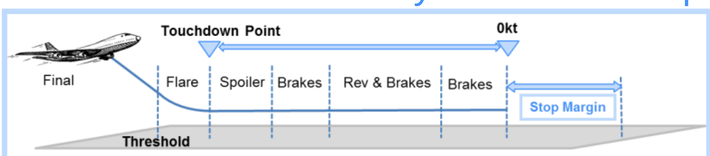
Runway Overrun Example
Change management

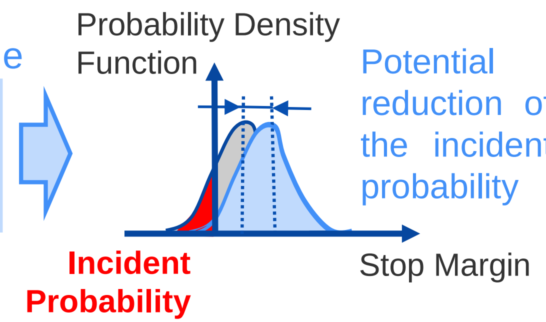
- How can you quantify the effectiveness of risk mitigation measures **before** implementing them?
- Incident models can be assessed by FDM-based contributing factors or by proposed ('artificial') distributions of contributing factors





Incident Model - Runway Overrun Example





Incident models allow the assessment of potential changes in flight operations, such as

- Limits (e.g. maximum tailwind component)
- Expected value/standard deviation of contributing factors (e.g. approach speed, touchdown behavior, …)
- Safety/risk assessments of new airports

Summary

- We focus on the next generation of airline Safety Management Systems that include a **predictive component.**
- Predictions are based on incident models that **take physical, technical and operational aspects into account**.
- Contributing factors are based on the airline's FDM data and **modeled as probability distributions**.
- Relate the statistics of contributing factors to the occurrence probability of incidents
- Incident probabilities are continuously computed (trend monitoring)
- By **using non-Gaussian distributions,** we account for "extreme" values.
- It enables a statistically qualified quantification of incident & accident probabilities **within a single airline** along with the **identification and quantification** of the driving factors.
- Answering the questions every flight safety manager should ask, such as:
  - What is the most likeliest incident in my airline?
  - What is the most likeliest path to an incident?

Thank you! Any Questions?

Professor

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