The role of safety validation in ATM concept development: How does it work in practice?

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Motivation and purpose

Development of advanced air traffic operations
- A challenge to satisfy a multitude of heterogeneous requirements from multiple stakeholders
- Effective feedback from validation to development and decision-making is crucial

How does this work in practice?

A practical example of advancing operations for Amsterdam airport
- Crucial role of validation of safety performance
- Many lessons learned
- Initially several advanced solutions were considered, but eventually a simpler, but more costly solution was implemented
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- **Design challenge faced**
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Design challenge faced

- New runway 18R/36L
- Runway 18C/36C between terminals and new runway
- Capacity needs for simultaneous usage of runways 18R/36L and 18C/36C
Active runway crossings?  Southern taxiway?  Northern taxiway?
Initial safety studies by external company: each option can be made safe

Decision:
1. Active runway crossings
2. Southern taxiway (as back-up)

ICAO recommendation not to introduce active runway crossings when developing airport

Thus, safety requirements included:
- Runway control concept
- Runway Incursion Alerting System (RIAS)

From here, LVNL took over the development & validation process from the airport
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Development and validation approach

LVNL’s integrated VEM Management:
- Veiligheid (Safety)
- Efficiency (Efficiency)
- Milieu (Environment)

Design/ validation cycle:
- Decision by management
- Concept design by development team
- Validation of concept by VEM analysis team
- Communication of validation results
- Go/ no-go decision by management
- If no-go, development team is asked for potential options of design improvement
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Cycle 1: Active runway crossings

**Decision:** Further develop the active runway crossing operation

**Design:** Detailed design of active runway crossings

**Validation approach:** Basic risk analysis steps with event-sequence model

**Validation results:**
- Hazards not previously identified; e.g., R/T confusion, unavailability of R/T frequency
- It could not be assured that risks of collision for crossing and take-off would be acceptable, and criticality of risk was unrelated to RIAS parameters

**LVNL decision:** No implementation; new development cycle 2a

**NLR decision:** Further research on the first design, with more advanced safety assessment approach (new validation cycle 2b)
Cycle 2a: Adapted active runway crossings

Decision: Re-design the crossing operation

Design: Main changes with previous design:
- Runway controller 18C/36C controls only one runway
- Crossing starts further away from runway

Validation approach: VEM analysis with
- Similar approach for safety
- Investigation of crossing procedures on other airports

Validation result: It could still not be assured that all risks would be acceptable
- Accident rates at other airports in same order of magnitude as assessed risks

Decision: no implementation
Cycle 2b: Original active runway crossings

**Aim:** Gain more grip on dynamic and dependent character of crossing operation in new cycle, by NLR and NASA

**Design:** Same as cycle 1

**Validation approach:** Monte Carlo simulations using dynamic risk model

**Validation result:** Confirmation of criticality of risk
- Approach in cycles 1 and 2a may have underestimated risk.
- ATCo reaction on RIAS alert may arrive when pilot already solving the conflict; ATCo perceives to play a key role in conflict resolution
Cycle 3: Taxiing on southern taxiway

Decisions:

- No structural active runway crossings
  - Decreased confidence in reaching VEM objectives
  - Role of ATCos’ acceptance
  - ICAO recommendation
- Permanent solution: independent taxiing via southern or northern taxiway, depending on direction of usage of runway 18C/36C
- Temporary solution needed: northern taxiway not yet available!
Cycle 3: Taxiing on southern taxiway

**Design:** Dependent taxiing operation on southern taxiway
- Switchable stop bars
- Controlled by RC 18C/36C

**Validation approach:** VEM analysis
- Event-sequence model
- Monte Carlo simulations with dynamic risk modelling

**Validation result:** Safety and capacity objectives achieved

**Decision:** Implement design as temporary solution
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Comparison with literature

Waterfall model & V-model assume that problems can be foreseen.

Spiral model [Boehm 1988]: development of complex designs.

The development and validation process studied here appears to fit this spiral model.
Observation 1: Cycles focused on active runway crossings; implemented operation features independent taxiing via perimeter taxiways

- Seemingly less promising solutions may turn out to be preferred
- At the start of a new cycle, generate new alternatives and consider already identified options, and their existing validation results
- Need to store design alternatives and validation results

Observation 2: When selecting options for further design:

- do not base the decision on assessed performance of the evaluated options alone
- also consider their potential for further redesign
Observation 3: Quality of concept development and quality of safety assessment can have major effect on the process, and hence on duration and investments

- What if powerful safety risk assessment tools would have been available from the start?
- Learning curve: developers, validation team, and decision-makers learned how to communicate with and learn from each other
Valuable example in learning from applying various methods towards safety assessment:

- Key roles of ATCos and pilots in most steps of the safety risk analyses of cycles 1 and 2b [De Jong et al., 2006].

- Novel hazard identification approach and its results in cycle 1 [De Jong et al., 2007].

- Dynamic risk modelling and Monte Carlo simulation approach of cycle 2b, and its results [Blom et al., 2006] & [Stroeve et al., 2008].

- Benchmark of event-sequence approach of cycle 1 with Monte Carlo approach of cycle 2b: significant differences [Blom et al., 2008]
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Initial analysis of development and validation practice at LVNL for a challenging practical problem shows:

- The factual process appears to fit the spiral model of [Boehm, 1988]
- Effective interaction of operational concept developers, validation experts, and LVNL decision-makers played a key role
- Design alternatives should not be discarded because they may appear to be of value later
- Quality of concept development and of safety assessment can have a major impact on duration and investments to realize an operation

For complex designs, validation is most of the time invalidation. Only the last cycle prior to operation is validation!
Question?

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