STPA for Airports

safety hazard analysis for aircraft operations in hub airports

Idaldo J Lima       Claudio J P Alves       Carlos H N Lahoz
Aeronautics Institute of Technology - ITA (Brazil)

2018 MIT STAMP/STPA Workshop - March 29
Disclaimer

The views, opinions and assumptions expressed in this presentation are those of the authors and do not necessarily reflect the official policy or position of the Brazilian Government or any of its organisations, including the Aeronautic Technology Institute (ITA), or of the Massachusetts Institute of Technology (MIT). Examples of analysis performed within this presentation are part of an ongoing work yet to be finished and made available. They should not be applied in real-world analytic products as they are based in dated public source information.
Agenda

1. context & prior work
   a. ongoing
   b. main idea

2. what & how
   a. process overview
   b. airport groups
   c. accidents of interest
   d. case study

3. applying STPA
   a. foundations
   b. unsafe controls
   c. scenarios

4. contributions
1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. APPLYING STPA
4. CONTRIBUTIONS
ongoing work

Master’s in Air Transportation and Airports
Aviation Infrastructure Engineering Graduate Program
Aeronautics Institute of Technology - ITA

**STAMP Approach Applied to Safety Hazard Analysis in Brazilian Airport Infrastructure**

supervisor: Prof. Claudio J P Alves
co-supervisor: Prof. Carlos H N Lahoz

objective: “to analyse safety hazards in aircraft operations for Brazilian airports using STPA and propose recommendations”
main idea on how

common INPUTS from group of cases

common OUTPUTS for group of cases

“THE STPA PROCESS“

extendable results, less time and effort for analyses
1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. APPLYING STPA
4. CONTRIBUTIONS
process overview

AIRPORTS & ACCIDENTS GROUPING

use safety context attributes to group airports and accidents

Airport Characterization Through System Safety Contexts
at SITRAER 2017

STPA ANALYSIS

apply STPA analysis within airports groups and accident types

STPA for Airports safety hazard analysis for aircraft operations in hub airports
at 2018 MIT STAMP Workshop

RECOMMENDATIONS GENERATION

produce recommendations for airports within groups

Master’s dissertation and paper
at ITA Infra July 2018
airport groups

“Airport Characterization Through System Safety Contexts”
at SITRAER 2017

method: Two-Step Cluster Analysis
attributes:

**APPROACH**
- level of precision available
  - PA1/2/3A, NPA, NINST

**MOVEMENT**
- annual aircraft movs
  - last 10 years average

**SECURITY**
- protection levels
  - AP-3/2/1/0 or AD

**OPERATION**
- maintenance & emergency standards
  - Class I, II, III or IV

**FEEING**
- category
  - 1st, 2nd, 3rd, 4th Class or Concession
### Airport Clusters

<table>
<thead>
<tr>
<th>CLUSTER 1</th>
<th>CLUSTER 2</th>
<th>CLUSTER 3</th>
<th>CLUSTER 4</th>
<th>CLUSTER 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP-1 100%</td>
<td>AP-0 100%</td>
<td>AP-2 100%</td>
<td>AD 58,54%</td>
<td>AP-3 100,00%</td>
</tr>
<tr>
<td>Class I 66,67%</td>
<td>Class I 96,67%</td>
<td>Class II 20,83%</td>
<td>Classe IV 100%</td>
<td></td>
</tr>
<tr>
<td>Class II 33,33%</td>
<td>Class II 3,33%</td>
<td>Class III 79,17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57 airports</td>
<td>30 airports</td>
<td>24 airports</td>
<td>41 airports</td>
<td>12 airports</td>
</tr>
<tr>
<td><strong>Regional</strong></td>
<td><strong>Local</strong></td>
<td><strong>Domestic</strong></td>
<td><strong>Local</strong></td>
<td><strong>Int. Hub</strong></td>
</tr>
<tr>
<td>2ª 50,88%</td>
<td>2ª 66,67%</td>
<td>1ª 29,17%</td>
<td>4ª 80,49%</td>
<td></td>
</tr>
<tr>
<td>3ª 26,67%</td>
<td>4ª 66,67%</td>
<td>1ª (* 4,17%</td>
<td>- 80,49%</td>
<td>1ª 58,33%</td>
</tr>
<tr>
<td>4ª 62,93%</td>
<td>1ª (* 29,17%</td>
<td>1ª 58,33%</td>
<td>1ª 58,33%</td>
<td></td>
</tr>
<tr>
<td>2335 mov/y</td>
<td>635 mov/y</td>
<td>14725 mov/y</td>
<td>461 mov/y</td>
<td>92552 mov/y</td>
</tr>
<tr>
<td><strong>Regional Airports</strong></td>
<td><strong>Local Airports</strong></td>
<td><strong>Domestic Airports</strong></td>
<td><strong>Local Airports</strong></td>
<td><strong>Int. Hub Airports</strong></td>
</tr>
<tr>
<td>NINST 22,81%</td>
<td>NINST 56,67%</td>
<td>NINST 75,61%</td>
<td>NINST 75,61%</td>
<td></td>
</tr>
<tr>
<td>NPA 66,67%</td>
<td>NPA 40,00%</td>
<td>NPA 24,39%</td>
<td>NPA 24,39%</td>
<td></td>
</tr>
<tr>
<td>PA1 10,53%</td>
<td>PA1 3,33%</td>
<td>PA1 33,33%</td>
<td>PA1 33,33%</td>
<td></td>
</tr>
<tr>
<td>2335 mov/y</td>
<td>635 mov/y</td>
<td>14725 mov/y</td>
<td>461 mov/y</td>
<td>92552 mov/y</td>
</tr>
</tbody>
</table>
case study

MAJOR HUB AIRPORTS (cluster 5)

- BSB  Brasília
- CNF  Confins
- CWB  Curitiba
- FOR  Fortaleza
- GIG  Galeão
- GRU  Guarulhos
- VCP  Campinas
- POA  Porto Alegre
- REC  Recife
- SDU  Rio de Janeiro
- CGH  São Paulo
- SSA  Salvador
accidents of interest

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARC</td>
<td>abnormal runway contact</td>
</tr>
<tr>
<td>GCOL</td>
<td>ground collision</td>
</tr>
<tr>
<td>LOC-G</td>
<td>loss of control on ground</td>
</tr>
<tr>
<td>RE</td>
<td>runway excursion</td>
</tr>
<tr>
<td>RI</td>
<td>runway incursion</td>
</tr>
<tr>
<td>USOS</td>
<td>undershoot/overshoot</td>
</tr>
<tr>
<td>TOF</td>
<td>takeoff</td>
</tr>
<tr>
<td>APR</td>
<td>approach</td>
</tr>
<tr>
<td>LDG</td>
<td>landing</td>
</tr>
<tr>
<td>TXI</td>
<td>taxi</td>
</tr>
<tr>
<td>STD</td>
<td>standing</td>
</tr>
</tbody>
</table>

CLUSTER 5 - MAJOR HUB AIRPORTS in Brazil

- **RI**: 9.4%  
- **USOS**: 12.5%  
- **ARC**: 14.0%  
- **LOC-G**: 23.5%  
- **GCOL**: 40.6%
case study

“STPA for aircraft operations in major hub airports” at MIT STAMP 2018

“GROUND COLLISION occurrences during TAXI and STANDING phases for the Brazilian MAJOR HUB AIRPORTS (cluster 5)”

21 reports from CENIPA (Brazilian equivalent to NTSB for aviation)

www2.fab.mil.br/cenipa
WHERE DID IT HAPPEN?

<table>
<thead>
<tr>
<th>Airport</th>
<th>Location</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSB</td>
<td>Brasília</td>
<td>5</td>
</tr>
<tr>
<td>CNF</td>
<td>Confins</td>
<td>0</td>
</tr>
<tr>
<td>CWB</td>
<td>Curitiba</td>
<td>1</td>
</tr>
<tr>
<td>FOR</td>
<td>Fortaleza</td>
<td>0</td>
</tr>
<tr>
<td>GIG</td>
<td>Galeão</td>
<td>4</td>
</tr>
<tr>
<td>GRU</td>
<td>Guarulhos</td>
<td>5</td>
</tr>
<tr>
<td>VCP</td>
<td>Campinas</td>
<td>0</td>
</tr>
<tr>
<td>POA</td>
<td>Porto Alegre</td>
<td>1</td>
</tr>
<tr>
<td>REC</td>
<td>Recife</td>
<td>0</td>
</tr>
<tr>
<td>SDU</td>
<td>Rio de Janeiro</td>
<td>1</td>
</tr>
<tr>
<td>CGH</td>
<td>São Paulo</td>
<td>2</td>
</tr>
<tr>
<td>SSA</td>
<td>Salvador</td>
<td>2</td>
</tr>
</tbody>
</table>

GCOL during TXI or STD
case study

“GROUND COLLISION occurrences during TAXI and STANDING phases for the Brazilian MAJOR HUB AIRPORTS (cluster 5)”

GROUND COLLISION
aircraft impact against AIRCRAFT, OBSTACLE or VEHICLE

TAXI & STANDING
aircraft in movement or not, on the surface of aerodrome excluded TOF and LDG

MAJOR HUB AIRPORTS (cluster 5)
BSB   CNF   CWB   FOR   GIG   GRU
VCP   POA   REC   SDU   CGH   SSA
case study

GROUND COLLISION during TAXI & STANDING

A330 against floodlight tower at BSB in 2013

http://www.potter.net.br/show_fnco/201304131652552
case study

GROUND COLLISION during TAXI & STANDING

A330 against floodlight tower at BSB in 2013
case study

GROUND COLLISION
during
TAXI & STANDING

B777 against B737 at GIG in 2013

http://www.potter.net.br/show_fnco/201309047438886
case study

GROUND COLLISION during TAXI & STANDING

B777 against B737 at GIG in 2013
case study

GROUND COLLISION during TAXI & STANDING

B777 against B737 at GIG in 2013
1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. APPLYING STPA
4. CONTRIBUTIONS
losses

Case
Ground collision occurrence during aircraft operations on the ground in major hub airports.

L-1  Loss of life or injury to people  (0 occurrences)
L-2  Loss of or damage to aircraft  (21 occurrences)
L-3  Loss of or damage to service vehicle/equipment  (11 occurrences)
L-4  Loss of or damage to infrastructure components  (8 occurrences)
L-5  Loss of transportation  (18 occurrences)
hazards

H-1  Aircraft violates the minimum separation from other aircrafts during operations on the ground [L-1, L-2, L-5]
H-2  Aircraft violates the minimum separation from service vehicles during operations on the ground [L-1, L-2, L-3, L-5]
H-3  Aircraft comes too close to service equipment components during operations on the ground [L-1, L-2, L-3, L-5]
H-4  Aircraft comes too close to airport infrastructure components during operations on the ground [L-1, L-2, L-4, L-5]
H-5  Airframe integrity is lost during operations on the ground [L-1, L-2, L-5]
H-6  Service vehicle/equipment frame integrity is lost during operations on the ground [L-1, L-3, L-4]
H-7  Airport infrastructure component integrity is lost during operations [L-1, L-2, L-3, L-4, L-5]
H-8  Human physical integrity is lost during operations [L-1, L-5]
functional control structure
96 UCAs identified so far
unsafe control actions

for the Control Action:
from Gnd Crew to Aircrew

GndCrew-CA-1: Apron Orientation
CA-1.1: Access Apron
CA-1.2: Transit through Apron
CA-1.3: Hold position
<table>
<thead>
<tr>
<th>Control Actions from Gnd Crew to Aircrew</th>
<th>Not providing causes hazard</th>
<th>Providing causes hazard</th>
<th>Too early, too late, out of order</th>
<th>Stopping too soon, applying too long</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Apron</td>
<td>UCA-1: when the alternative is restricted/closed and hold position is not an option</td>
<td>UCA-2: when there are latent restrictions ahead</td>
<td>UCA-4: when it is no longer possible</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UCA-3: when it should be for Other Aircrew</td>
<td>UCA-8: too late, when it is no longer possible</td>
<td>UCA-10: for too long, when there are latent restrictions/obstacles ahead</td>
</tr>
<tr>
<td>Transit through Apron</td>
<td>UCA-5: when the alternative is restricted/closed and hold position is not an option</td>
<td>UCA-6: when there are latent restrictions ahead</td>
<td>UCA-9: in the wrong order, during normal operations</td>
<td>UCA-11: when there are latent restrictions/obstacles ahead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UCA-7: when it should be for Other Aircrew</td>
<td>UCA-12: during normal operations without any restrictions/obstacles ahead</td>
<td>UCA-13: when there are latent restrictions/obstacles about to take place</td>
</tr>
<tr>
<td>Hold position</td>
<td>UCA-11: when there are latent restrictions/obstacles ahead</td>
<td>UCA-12: during normal operations</td>
<td>UCA-14: too soon, during normal operations</td>
<td>UCA-15: too late, when it is no longer possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UCA-13: when it should be for Other Aircrew</td>
<td>UCA-16: in the wrong order, during normal operations</td>
<td>UCA-17: for too long, when there are latent restrictions/obstacles still in place</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UCA-14: too soon, during normal operations</td>
<td>UCA-18: stop too soon, when there are latent restrictions/obstacles still in place</td>
<td></td>
</tr>
</tbody>
</table>
causal scenarios

S-1: Gnd Crew does not orient Aircrew to access Apron TBD when the alternatives are restricted/closed and hold position is not an option [UCA-1], because the control algorithm specified by Infraero for the Gnd Crew have a flawed implementation. This may cause its decision making to be inadequate and, consequently, its behaviour, unsafe. This could lead to aircraft violating minimum separations, coming to close to other parties, or even loss of integrities to any involved parties [H-1 to H-8].

(...)

24 CSs for UCA-1
496 CSs for GndCrew-CA-1
so far
1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. APPLYING STPA
4. CONTRIBUTIONS
contributions

✔ Major problems identified for the airport case study
feedback, coordination, mental models, procedures, (...)

✔ Results applicable to the airports with accidents
and extendable to other airports within the same cluster
less time and effort per analysis

✔ Arguments to Airport Operator and Regulator
Visual and understandable method to show flaws
and how to deal with it from a top-to-bottom perspective

✔ Many gains on applying STPA
better understanding of the system itself
human error properly addressed
easy process automation & verification
next steps on this research

Finish full analysis
by April 2018

Validate with Infraero
by May 2018

**STPA for Airports: safety hazard analysis for aircraft operations in hub airports**
paper to be published by May 2018

**STAMP Approach Applied to Safety Hazard Analysis for Brazilian Airport Infrastructure**
Master’s dissertation to be presented due July 2018 and main paper to be published due September 2018
Questions?

STPA for Airports

safety hazard analysis for aircraft operations in hub airports

Idaldo J Lima  Claudio J P Alves  Carlos H N Lahoz

Aeronautics Institute of Technology - ITA (Brazil)

idoaldolima@gmail.com

2018 MIT STAMP/STPA Workshop - March 29