ISRCS 2011

Toward providing guidance for procedure design

Formal definitions of procedure characteristics

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PURDUE UNIVERSITY

SCHOOL OF INDUSTRIAL ENGINEERING

SMOKE / FUMES OF UNKNOWN ORIGIN

CAB BUS P/B ----------OFF

Pause long enough for cabin crew to evaluate whether smoke or fumes decrease.

SMOKE / FUMES DECREASE

NO

Continue with cabin bus inoperative.

END

CAB BUS P/B ----------ON

SMOKE ELEC/AIR Selector ----------PUSH AND ROTATE

Rotate SMOKE ELEC/AIR Selector clockwise, pausing at each position long enough to evaluate whether smoke or fumes decrease. When a decrease is noted, leave selector in that position for rest of flight.
Continue with that generator channel and air system inoperative and **observe associated consequences.**

NOTE:
- When rotating the SMOKE ELEC/AIR Selector, the autothrottle will disengage and be unusable. The autopilot may disengage but then use another autopilot.
- Nuisance stick shaker may occur. (Stick shaker CBs on overhead panel: Captain E-1, F/O E-31)
- Following essential systems are inoperative or off in accordance with SMOKE ELEC/AIR Selector Pos:

SMOKE Selector Pos. 3/1 OFF:
only Captains VHF 1 and interphone available.
- DU 4, 5, 6; MCDU 2; FMS 2; IRS 2 (after 15 min).
- Radar 2; All Nav aids 2.
- BLEED AIR 1; PACK 1; ECON system; WING anti-ice.
- F/O pitot heat.
- Auto slat extension.
- Landing gear aural warning.
- Autobrakes.

FOR APPROACH:
- Set FLAP LIMIT Selector to OVRD 1.
- Go-around mode is not available.

SMOKE Selector Pos. 2/3 OFF:
-BLEED AIR 3; PACK 3; WING anti-ice.
-Aux pitot heat.
-Fuel dump low level.
-HORIZONTAL STABILIZER TRIM Switches on control column.
-Engine 2 reverser.

SMOKE Selector Pos. 1/2 OFF:
only VHF 2 and 3 available.
- DU 1, 2, 3; MCDU 1; FMS 1.
- IRS 1 and AUX IRS after 15 min, (AP no longer available).
- Radar 1; All Nav aids 1.
- BLEED AIR 2; PACK 2; WING and TAIL anti-ice.
- Captain pitot heat.
- GPWS, GPWS BELOW G/S lights.
- Auto ground spoilers.
- Engine reversers 1 and 3.

FOR APPROACH:
- Set FLAP LIMIT Selector to OVRD 2.
- On CAPT SISP push FD P/B to OFF.
- Go-around mode is not available.

If smoke/fumes are not eliminated, land at nearest suitable airport.

END

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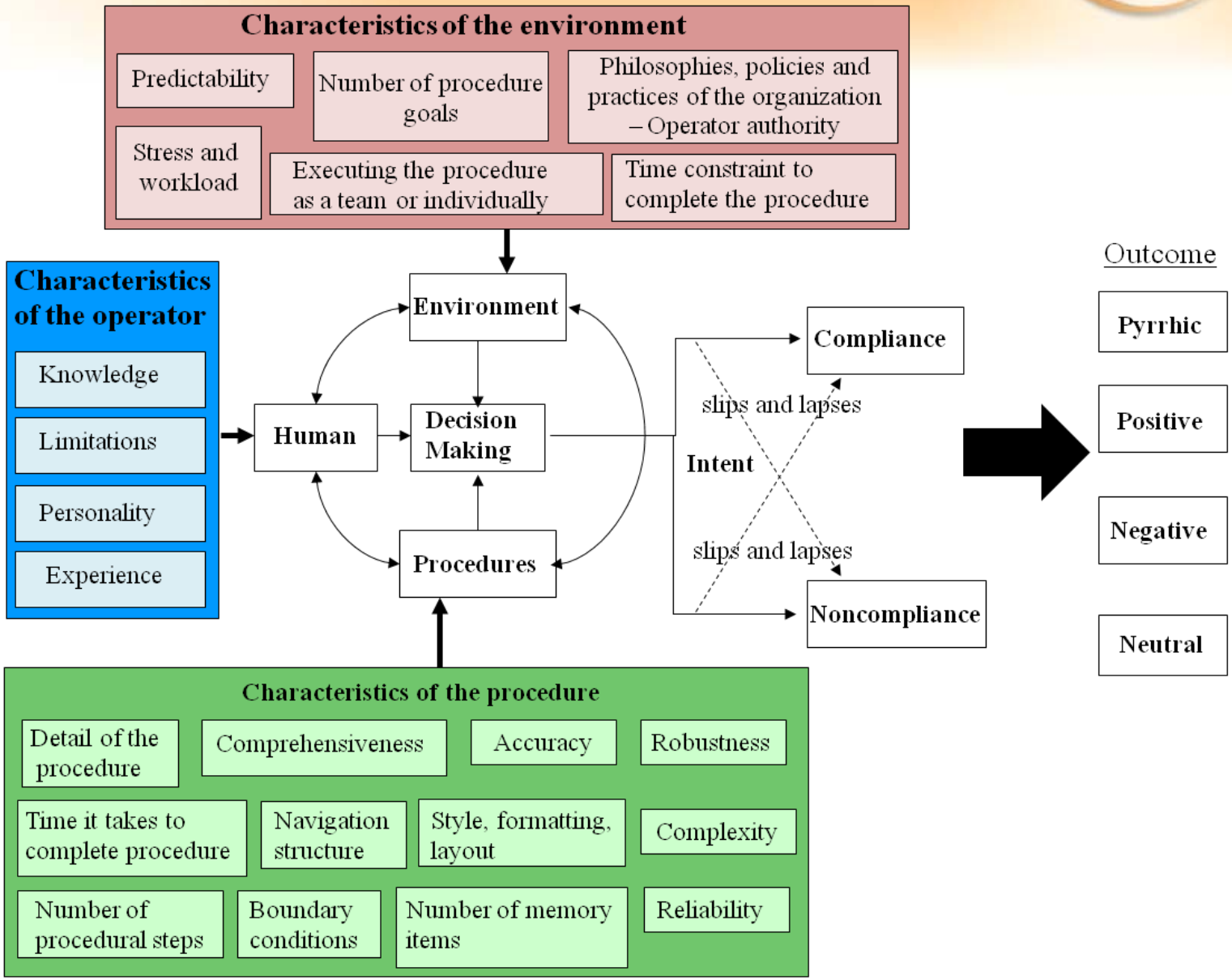
1	Diversion may be required.	
2	Oxygen masks (if required)	On, 100%
3	Smoke goggles (if required)	On
4	Crew and cabin communications	Establish
5	Manufacturer's initial steps	Accomplish
	Anytime smoke or fumes become the greatest threat, accomplish separate *Smoke or Fumes Removal Checkli*	
6	Source is immediately obvious and can be extinguished quickly: If YES → go to Step 7. If NO → go to Step 9.	
7	Extinguish the source. If possible, remove power from affected equipment by switch or circuit breaker on the flight deck or in the cabin.	
8	Source is visually confirmed to be extinguished: If YES → consider reversing manufacturer's initial steps. Go to Step 17. If NO → go to Step 9.	
9	Remaining minimal essential manufacturer's action steps [These are steps that do not meet the"initial steps" criteria but are probable sources.]	Accomplish
10	Initiate a diversion to the nearest suitable airport while continuing the checklist.	
	Warning: If the smoke/fire/fumes situation becomes unmanageable, consider an immediate landing.	
11	Landing is imminent: If YES → go to Step 16. If NO → go to Step 12.	
12	"X" system actions [These are further actions to control/extinguish source.] If dissipating, go to Step 16.	Accomplish
13	"Y" system actions [These are further actions to control/extinguish source.] If dissipating, go to Step 16.	Accomplish
14	"Z" system actions [These are further actions to control/extinguish source.] If dissipating, go to Step 16.	Accomplish
15	SFF continues after all system-related steps are accomplished: Consider landing immediately. Go to Step 16.	
16	Review Operational Considerations.	
17	Accomplish *Smoke or Fumes Removal Checklist*, if required.	
18	Checklist complete.	

Motivation and problem

- How can we compare checklists/procedures?
- How can we compare research results regarding procedures/checklists?
- How can design guidance be identified from research results?
- Problem: we can’t do these things without a formal language for discussing procedures/checklists.

Approach

- About what are we concerned in analyzing procedure following?
  - Compliance?
  - Outcomes?
- Develop formal definitions for procedures/checklists
- Identify design tradeoffs
- *(Exercise those definitions in a set of experiments)*


Characteristics of the environment
Predictability
Number of procedure goals
Philosophies, policies and practices of the organization – Operator authority
Stress and workload
Executing the procedure as a team or individually
Time constraint to complete the procedure
Characteristics of the operator
Knowledge
Limitations
Personality
Experience
Environment
Human
Decision Making
Procedures
Compliance
slips and lapses
Intent
slips and lapses
Noncompliance
Outcome
Pyrrhic
Positive
Negative
Neutral
Characteristics of the procedure
Detail of the procedure
Comprehensiveness
Accuracy
Robustness
Time it takes to complete procedure
Navigation structure
Style, formatting, layout
Complexity
Number of procedural steps
Boundary conditions
Number of memory items
Reliability

Enumeratable characteristics

Navigation structure $NS \in \{\text{Linear}, \text{Out/In}, \text{Hierarchy}, \text{Simultaneous}, \text{Tree}, \text{Mixed}\}$

Style, formatting, and layout can also be enumerated in this way.

Countable characteristics

Number of steps $Span(CL) = M$

Number of memory items $Span(CL_{memory})$

Time to complete may be any parameter of the distribution of time it takes to complete the procedure/checklist, may be the distribution itself, or may be the operator's perception of the time to complete.

Remaining characteristics require definition

- Detail, complexity: intrinsic to procedure/checklist
- Boundary conditions, reliability, robustness, accuracy , comprehensiveness: related to outcomes

Set of possible "strings" of interactions that can be used to accomplish an individual step of the procedure/checklist

$$s_{i,j} = \left\{ s_{i,1}, \ldots, s_{i,n(i)} \right\}; i = [1, M]$$

n(i) is the number of possible strings for step *i*

Each string made up of a sequence of interaction primitives

$$s_{i,j} = o_{i,j,1} \ldots o_{i,j,K(i,j)}; o_{i,j,k} \in \Theta, \forall i, j, K(i, j)$$

There are $K(i, j)$ interactions in each string of each step, each of which come from a possible set of interactions $\Theta = \{\theta_1, \ldots, \theta_P\}$

Detail & complexity

Procedure detail: inverse of the average number of ways one could accomplish the step in the procedure. If there is only one way, then *PD* = *1*. As *n(i)*→∞, *PD*→*0*.

$$PD = \frac{M}{\sum_{i=1}^{M} n(i)}$$

Complexity defined, in part, using Shannon entropy, and is roughly based on work defining complexity for physical phenomena*, although procedures are neither stationary nor ergodic. It attempts to capture the variability in how a procedure/checklist could be accomplished.

$$PC = \sum_{i=1}^{M} \sum_{k=1}^{K(i)} \sum_{p=1}^{P} p_{i,k,p} \log_2 p_{i,k,p}$$

where

$$P_{i,k,p} = \frac{\sum_{j=1}^{n(i)} \Upsilon(i,j,k,p)}{n(i)}$$

and

$$\Upsilon(i,j,k,p) = \begin{cases} 1, o_{i,j,k} = \theta_p \\ 0, \text{ otherwise} \end{cases}$$

*Grassberger, P., 1986. Toward a quantitative theory of self-generated complexity. *International Journal of Theoretical Physics*, *25*, 907–938

Remaining definitions

Boundary conditions:

Ideal $BC = \{BC_1, BC_2, \ldots, BC_n\}$ s.t. $\bigcap_{i=1}^{n} BC_i \rightarrow p\left(\text{positive outcome} \middle| \text{compliance}\right) = 1$

Designed[2] $BC^D = \left\{BC_1^D, BC_2^D, \ldots, BC_m^D\right\}$

Perceived $BC^K = \left\{BC_1^K, BC_2^K, \ldots, BC_m^K\right\}$

[2]compliance to the procedure/checklist is likely a boundary condition

Reliability[3] $p\left(\text{positive outcome} \middle| \bigcap_j BC_j^D = true\right)$

Robustness[3] $p\left(\text{positive outcome} \middle| \bigcap_j BC_j^D = false\right)$

These definitions are overly simplistic and ignore the weighting and degree of different violations of BC.

Comprehensiveness[3] $\dfrac{\sum_{i=1}^{m} p\left(BC_i^D = false\right)}{\sum_{j=1}^{n} p\left(BC_j = false\right)}$

[3]since *BC* is not identifiable to designers, these measures must be obtained empirically.

Tradeoffs

High level desired Low level desired	Reliability	Robustness	$BC^D \cap BC$	Complexity	Time to perform the procedure
Reliability[4]	•	–	+	+	+
Robustness[5]		•	–	+	+
$BC^D \cap BC$			•	+	+
Complexity				•	+
Time to perform the procedure					•

[4]Table assumes we increase reliability by expanding the designed boundary conditions.
[5]Table assumes we increase robustness by trimming the designed boundary conditions.

Summary

- We now have a symbolic framework that allows us to compare checklists/procedures and research results.
  - Formal – provides consistency across applications/domains
  - Focuses on outcomes and not compliance
- Research results may then be transferrable across domains.
  - What is the effect of reducing detail?
  - What is the effect of increasing reliability?
- Procedure/checklist design involves a series of tradeoffs – e.g., I can increase detail, but that means increasing complexity.
- <u>Next steps:</u>
  - Filling in the gaps
  - Validation
  - Experimentation

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