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Automated Border Control systems as part of e-border crossing process

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Disclaimer:

The term ABC used in this paper does not refer to and does not have any association with the CBSA’s Automated Border Clearance program and is used solely in reference to a general system that performs automated clearance of travellers at the border.

The terms eBorder, ePassport, eGate used in this paper do not refer to and do not have any association with any particular national program or deployment and are used solely in reference to a general automated border control/management infrastructure.

Outline

1. CBSA Context - DRDC CSSP Project
2. Quick scan of issues with existing systems:
   - Case Study 1: eGates (EU)
   - Case Study 2: RTP kiosk (UK IRIS)
   - Lessons learnt
3. Evolution of biometric border/access control systems
   - Three generations of ABC
4. Concept of Degraded Performance
5. Concept of Air Traveller Continuum and eBorder
   - Key components of eBorder
6. Formalized definition of ABC
   - ABC as evidence accumulating machine
   - ABC modeling for Cost-Benefit / Performance / Risk analysis

Conclusions

CBSA context - Technologies for Air Travel

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- Manual Primary Inspection Lane (PIL)
- TTP (Nexus): iris biometric kiosks

- TRBP: fingerprints for temporary residents
- ABC self-service declaration kiosks

+ ePassports (since 2013)
+ Passport readers for check-in (by Air Lines)

- Looking into the Future

4. Dmitry Gorodnichy et al. "*ABC as part of eBorder*" (NIST IBPC 2014)

CSSP-2013-CD-1020

Risk analysis of face and iris biometrics in automated border control applications (“RA-ABC” Project)

Lead Organization: CBSA

Partnership: University of Calgary

Start-End: June 3, 2013 – March 31, 2015

Funded: DRDC Center for Security Science

Canada Safety and Security Program

Objectives:

1. Perform a benefit-risk analysis for ABC systems
2. Determine a taxonomy of ABC systems
3. Develop a taxonomy of vulnerabilities and attacks
4. Identify technologies and procedures to secure biometric-based techniques
5. Generate protocols for rules and restrictions related to the testing/validation of ABC systems

Outcomes to date:

- “Automated Border Control machines: Overview, trends, and challenges”
    - “ABC systems as part of eBorder process”
- “Automated Border Control machines: Taxonomy of deployment scenarios”
- “Risks Evaluation for Biometric-based Automated Border Control Machines”
    - “Biometric-Based Authentication Profiler”

Canada

Quick scan of issues: EU eGates

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Performance in Germany:

(M. Nuppeney, “Automated Border Control based on (ICAO compliant) eMRTDs”, NIST IBPC, 2012)

- ≈ **500** users passing through EasyPASS per day
- **88%** success rate
  - border crossing without manual interaction
- **12%** operational reject rate
  - additional manual inspection by border guard
  - ≈ **5%** rejected due to face verification failed
    - **@** ≈ **0,1% FAR** (False Accept Rate)
  - ≈ **7%** rejected by the system due to other reasons
    - non compliant user behaviour
    - document check failed
    - hits from background database checks

Note: 1 in 8 (12%) is rejected.

- did not understand or missed logistical signs
- did not know or forgot what kind of passport they hold
- did not follow instructions of the document reading machine,
- were in some other way imperfect subject for database processing

Quick scan of issues: EU eGates (cntd)

Performance in Spain:

(D.Cantarero et al. A multi-modal biometric fusion implementation for ABC Systems . 2013 European Intelligence and Security Informatics Conference)

Note: variation in performance

- Quality of biometric document ?
- User experience ?
- Difference in designs?
- “Doggington zoo” ?
- Language ? Duration of travel (Fatigue) ?

Note: transaction-based metrics used

- Number of users need to be reported !

TABLE II. 4 MONTH STATISTICS OF THE ORIGINAL DECISI

Country	Total ABC usage	Global Biometric FRR	Facial FRR
AUT	215	5.12%	5.12%
BEL	531	21.59%	21.59%
BGR	135	3.73%	3.73%
CHE	217	5.09%	5.09%
CYP	5	0.00%	0.00%
CZE	97	10.53%	10.53%
D	1,540	10.18%	10.18%
DNK	152	13.16%	13.16%
ESP	67,508	16.40%	13.34%
EST	15	7.14%	7.14%
FIN	155	4.52%	4.52%
FRA	2,687	12.69%	12.69%
GBR	10,914	7.54%	7.54%
GRC	187	2.67%	2.67%
HUN	70	8.57%	8.57%
IRL	749	8.58%	8.58%
ISL	10	0.00%	0.00%
ITA	2,757	15.79%	15.79%
LIE	1	0.00%	0.00%
LTU	56	8.93%	8.93%
LUX	13	0.00%	0.00%
LVA	56	1.79%	1.79%
MLT	10	10.00%	10.00%
NLD	990	13.54%	13.54%
NOR	97	16.49%	16.49%
POL	214	10.33%	10.33%
PRT	2,172	5.45%	5.45%
ROU	367	7.42%	7.42%
SVK	49	14.29%	14.29%
SVN	40	10.00%	10.00%
SWE	397	7.61%	7.61%
TOTAL	92,406	14.55%	12.32%

Quick scan of issues: UK IRIS

Due to be closed down… Six reported reasons:

1. "…passengers often spent longer being scanned by the machines than when they went through traditional passport control…"

2. "…it emerged that up to 1 in 10 travellers were wrongly rejected by the scanners, and then had to wait for manual checks to get through passport control…"

3. "…an increasingly large number of people, who are clearly not registered for IRIS, try to use the gates and then fail…"
4. "…whilst iris images are a secure biometric, they are not included in e-passports, which contain face (and fingerprint) data…

5. "…The money would be better spent employing more trained staff…
6. "…Technologies have a finite lifetime…"

[1] A.J. Palmer, C. Hurrey. **Ten Reasons Why IRIS Needed 20:20 Foresight. Some Lessons for Introducing Biometric Border Control Systems**, 2012 European Intelligence and Security Informatics Conference

[2] http://www.dailymail.co.uk/travel/article-2102489, https://aftermathnews.wordpress.com/2012/02/28

Quick scan of issues: UK IRIS (cntd)

Critical Observation

Q553 Dr Turner: *Can you give me your views, please, on the risks involved in this project [IRIS], and do you think that the Home Office has considered them seriously enough?*

Dr Mansfield: *. . . The risks I would say are probably because it is a very large project, a very large procurement, of which biometrics is just one small part. There seems to have been a focus on the biometric element as being the most technical and perhaps least understood element of the whole scheme, and to my mind assuming that is where all the risks lie is totally incorrect.*

UK Parliament, Examination of Witnesses (Question 540-559), May 3, 2006 http://www.parliament.the-stationery-office.co.uk/pa/cm200506/cmselect/cmsctech/1032/6050307.htm

Conclusions for quick scan

ABC Performance (Reliability, Facilitation, Cost) =

= Function (Technical factors, Non-technical factors)

- *Technical factors* can be efficiently controlled. For example:
  - performance of deployed recognition algorithms can be improved
  - machine-human interfaces can be designed with abilities to adapt to the user
  - ergonomic of man-traps and e-gates can be improved
  - human and machine operations can be better balanced
  - airport logistics can be modernized
  - border officers can be better trained to deal with abnormal situations

- *Non-technical factors* are hard or impossible to control. Include:
  - social, ethnic, cultural, religious,
  - linguistic
  - psychological,
  - geographical factors

Conclusions for quick scan (cntd)

- A substantial percentage of failure is due to sources of risk other than those related to the biometric recognition performance

- Because an ABC system is just one of many components in a complex semi-automated multi-component border crossing process, any failure or risk related to the deficiency of the biometric recognition can be mitigated by other non-biometric means

➔ concept of Evolution of ABC Systems and their Evaluation

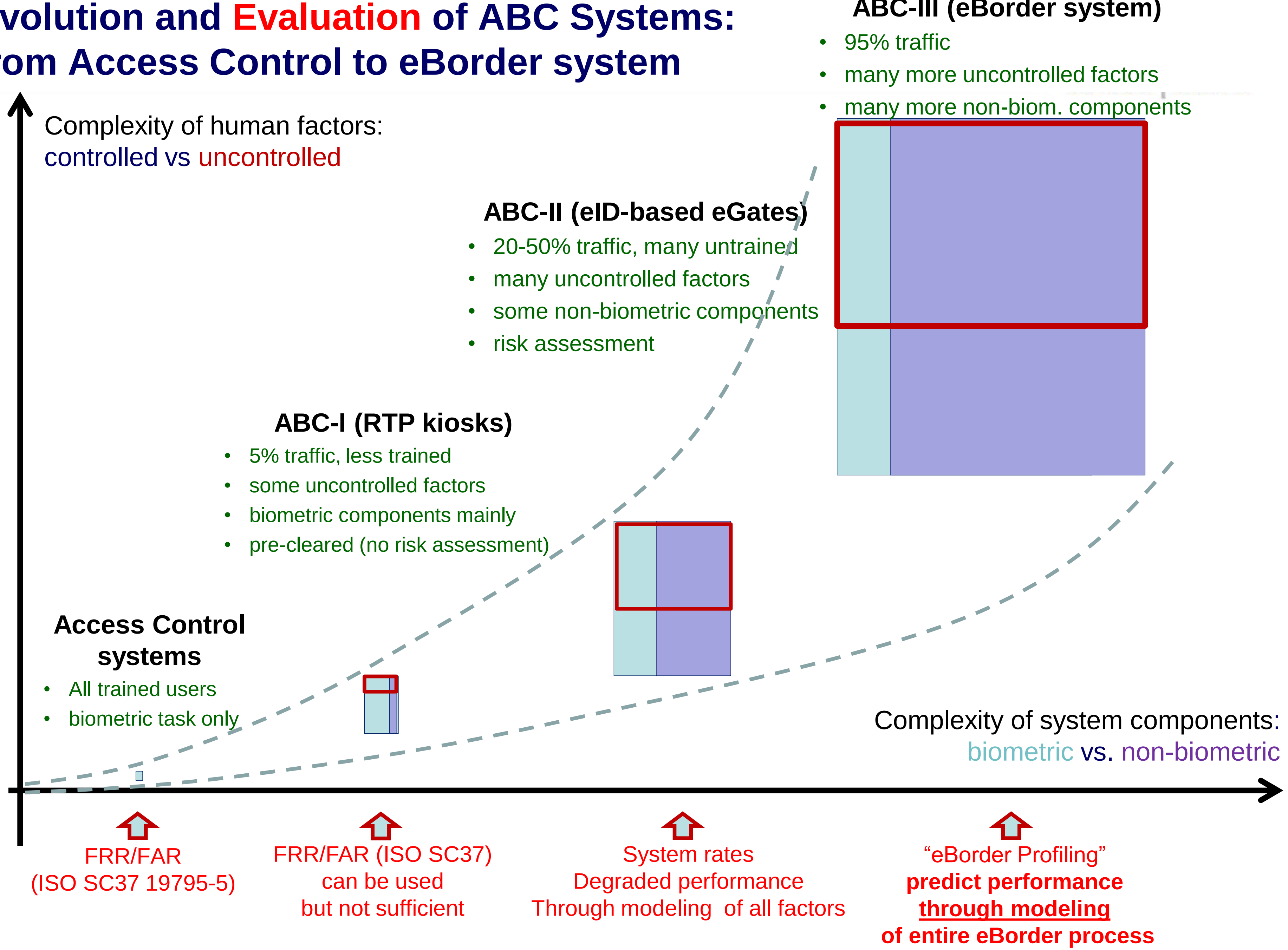
  ➔ Three Generations of ABC

  ➔ performance of ABC systems can no longer be measured in terms traditional metrics / curves (ISO SC 37)

➔ concept of *Degraded Performance*

➔ concept of *Air Traveller Continuum* (eBorder)

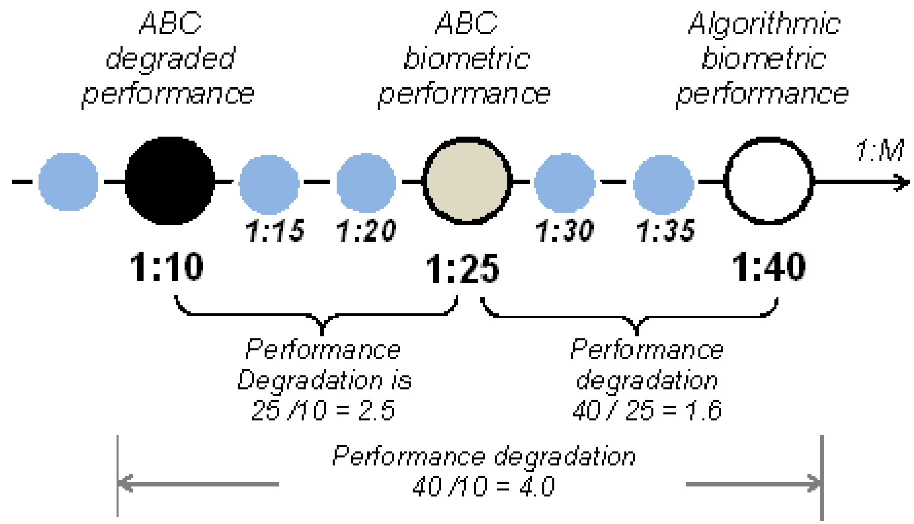
Evolution and Evaluation of ABC Systems: from Access Control to eBorder system



New concept: Degraded performance (DP)

Definition: Degraded performance is a statistical metric, which represents the real performance of the system, which is different from the desired performance, or the predicted limit of the performance.

- The real performance is always less than the desired performance, or its predicted limit.
- It is difficult or impossible to estimate the contribution of different factors to the system performance degradation.
- Reliability of the ABC can be measured using DP:



Definition: DP (ABC) is defined as the ratio of travelers for whom the ABC machine cannot confirm admissibility, and they have to be sent to the manual control; it is expressed as “1 in M travelers is directed to manual control”.

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DP: Why it is useful

- It carries the notion of the system *potential, ie available resource (best possible performance that* can be achieved, as reported in literature)

- It carries the notion of the *efficiency of utilization of a potentially available resource,* which represents the degree of the performance improvement.

- It distinguishes the system performance and the biometric performance in terms of (a) “1 in M is wrongly recognized” vs. (b) “1 in N is wrongly directed to manual control”.

- provides the means to distinguish the controlled and uncontrolled factors.

Level of degradation is a difference, or ratio, between the degraded performance and the performance of the biometric recognition algorithms.

DP: examples of use

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1. State-of-Art analysis:

Contemporary ABC machines operate at

- Degraded Performance = 1 in 10 travelers (1 : 10)

2. System potential analysis:

All deployed ABC machines have good resource for performance improvement:

- UK's IRIS utilized only 1/100 of its resource
- EU eGate utilize 1/10 of their potential resource.
- Spain's ABC machines based on fusion of face and fingerprint modalities have a hundred times more resource.

ABC machine, country	ABC machine degraded performance	ABC machine biometric performance	Algorithmic biometric performance
UK[32], [14]	1:10	1:50 (2%)	1:1,000 [a)]
Germany [59]	1:8	1:20 (5%)	1:100 [b)]
Germany [48]	1:7	1:20 (5%)	1:100 [c)]
Spain [10]	1:8	1:20 (5%)	1:100 [d)]
Spain [10]	1:10	1:25 (4%)	1:1,000 [e)]
Canada [53]	1:X	1:X	1:1,000 [f)]
France [63]	1:X	1:X	1:1,000 [g)]

a) *IRIS program for registered travelers. Performance of the iris recognition algorithm is expressed by FRR=0.1%*

b) *FRR=1% for facial recognition algorithm*

c) *FRR=1% for facial recognition algorithm*

d) *FRR=1% for facial recognition algorithm*

e) *total FRR=0.1% for fusion of facial and fingerprint modalities*

f) *NEXUS ABC machine (Canada/U.S.) for registered travelers. The iris recognition algorithm performance is FRR=0.1%*

g) *PARAFE program for French citizens (without pre-registration). The fingerprint recognition algorithm performance is FRR=0.1%*

DP: examples of use (cntd)

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3. **Controllable factors of degradation:**

A lot of effort was undertaken by various institutions such as NIST and ISO to improve the design and performance of the biometric recognition algorithms.

However, one can observe that <u>improving recognition algorithms does not necessarily result in performance improvement.</u>

4. **Uncontrollable factors of degradation:**

International community (ICAO, IATA, FRONTEX) demonstrated efforts to combat the increasing number of uncontrollable factors.

<u>Additional study in various non-technical fields is needed in order to shift the weight of the non-technical factors contributing to performance degradation, into the technical factors</u> that can be controlled much easier than the other ones.

“eBorder” concept

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- Term used by the Home Office (UK)
- Also known as Smart Borders or Border of the Future (Frontex,IATA,ICAO)

Definition: **eBorder = automated border control and management,** specifically for Air Mode of transportation (**Air Traveller Continuum**)

The key task of eBorder : to expedite the traveler’s passage and improve the border security through automation of traveller clearance process*.

Two traveller clearance functions :

1. traveler authentication – “Who are you?”
2. traveler risk assessment / screening - “What is your risk factor?”

ABC machine is main component in this e-Border task.

eBorder (Air Traveller Continuum)

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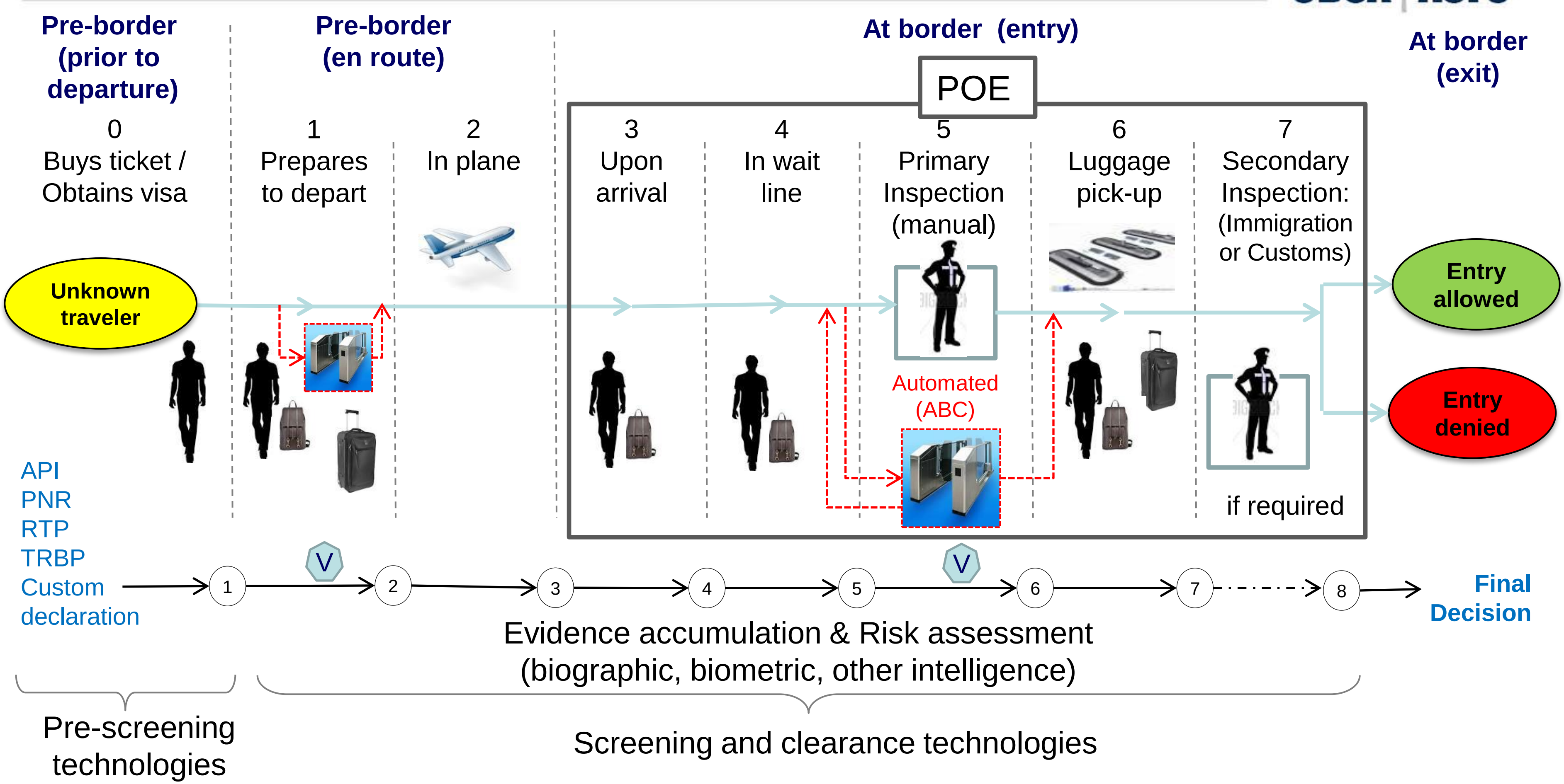

Key eBorder components:

I: “Three-lane” risk-based processing
II: manual behavior screening
III: automated behavior screening
IV: automated queuing
V: biometric systems (ABC): Gen-1, Gen-2, Gen-3

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Key components of eBorder

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I: "Three-lane" risk-based processing

Many topologies possible (inc. RTP)

II: Non-automated behavior screening (SPOT)

III: Automated behavior screening (AVATAR)

IV: Automated queuing (APC/ABC kiosks)

V: Biometric-enabled traveller clearance systems (ABC)

Key components* of eBorder (cntd)

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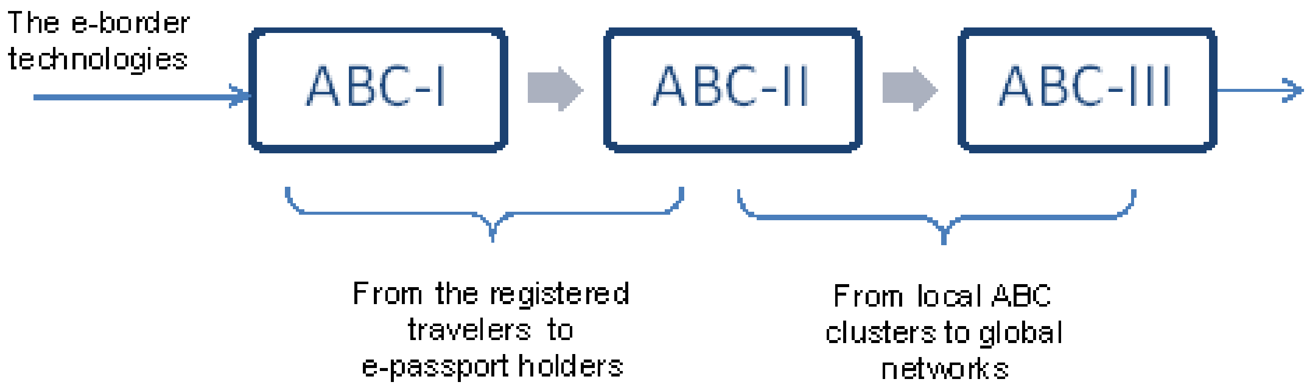
Traveller Pre-screening	"Three-lane" (three-level) risk-based processing	Non-automated behavioural screening	Automated behaviour screening	Intelligent Queuing	Biometric-enabled traveller clearance (aka ABC)
Assign a risk score to a traveller based on the information available about the traveller prior to travel (credit, criminal history, etc) The initial data is provided by the traveller when buying the ticket.	Divide travelers into defined risk categories: Fast clearance of for low-risk travellers ("green "lane"). Fast referral to secondary inspection for high-risk travellers ("red lane"). Main clearance effort is on travellers of unknown risk ("yellow "lane"). Division into "lanes" can be topological or logistical, either accelerated by traveller's involvement or not.	(No technology used. Based on human skill only) Trained Officers attempt to recognize terrorists and persons with aggressive intentions among travelers by visual observation.	(Evolved from lie and emotion detection) Detect hidden human intentions through fusion of multi-modal and multi-band biometrics combined with AI decision making dialog tools	Delegate the upstream border control to machines, and the downstream control to border officers	Person-interaction device with decision making mechanism automates traveller clearance through biometric authentication and risk assessment. Automates two tasks: -Traveller authentication (identifying a person) - Traveller clearance (deciding to refer the identified person to Exit or to manual Examination)
Examples: US (>2000): Computer-Assisted Passenger Pre-screening System **CAPPS**, CAPPS-II, Secure Flight. EU, UK (>2004): European External Border Surveillance System **EUROSUR**, **SEMAPHORE**	Examples: - Single physical lane: widely used at passport control as triaging-based questions - One or two physical lanes: **RTP** programs - Three physical lanes: TSA Diamond (by traveller's choice) - Two physical lanes: **APC**/ABC kiosks (by traveller's choice, according to citizenship)	Examples: Israel, Russia. US (since 2003): Screening Passengers by Observation Technique (**SPOT**), DARPA HumanID project	Examples: US (2006): **FAST** US,EU (2013): **AVATAR** kiosks	Examples: US, Canada: Deployed in Vancouver, Montreal, Toronto, and Chicago International Airports using self-service automated passport / border clearance (**APC**/ABC) kiosks	**Gen-1 ABC**: RTP-based (since 2002) Examples: UK: IRIS. Netherland: PREVIUM. Canada: NEXUS. **Gen-2 ABC:** eID/ ePassport based (since 2006) Examples: EU, Australia **Gen-3 ABC:** future machine of eBorder (2020)

* Each of these components contribute to the decision in Gen-3 ABC system

Three generations of ABC



- Gen-1 ABC (RTP-based): Nexus, IRIS, PRIVIUM > 2002
  - Defined by each state
- Gen-2 ABC (ePassport/eID-based): EU eGates > 2006
  - Defined by each state with common guidance
- Gen-3 ABC: machine of future eBorder > 2020
  - No formal definition, yet discussed in ICAO, Frontex roadmaps

Definitions: Gen-1 ABC and Gen-2 ABC

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Definition 1 [IATA]: (for registered travelers): "*The ABC is an automated border control system that either authenticates the travel documents, tokens or permits, or denies admission to a traveler according to some pre-established specifications.*"

- The ABC may additionally verify a passenger biometric data against the travel document and/or token, or a pre-existing database, containing biometric data.

Definition 2 [FRONTEX] (e-passport/e-ID holders): *"The ABC machine is an automated system which authenticates the e-MRTD (Machine Readable Travel Document), establishes whether the traveler is the rightful holder of the document, queries border control records and automatically determines eligibility for border crossing, according to certain pre-defined rules"*

- Biometrics authentication required by definition

Definition: Gen-3 ABC

<u>Definition 3</u>: ABC is the system that satisfies the following properties:

•*Property 1:* It makes use of the entire airport infrastructure and related processes.

•*Property 2:* It is a large-scale system.

•*Property 3:* It performs authentication of travelers.

•*Property 4:* It is a semi-automated system that operates under supervision of a border officer.

•*Property 5:* It is a <u>risk assessment system</u> that <u>analyzes available information about each traveler</u> and assigns him/her a risk factor.

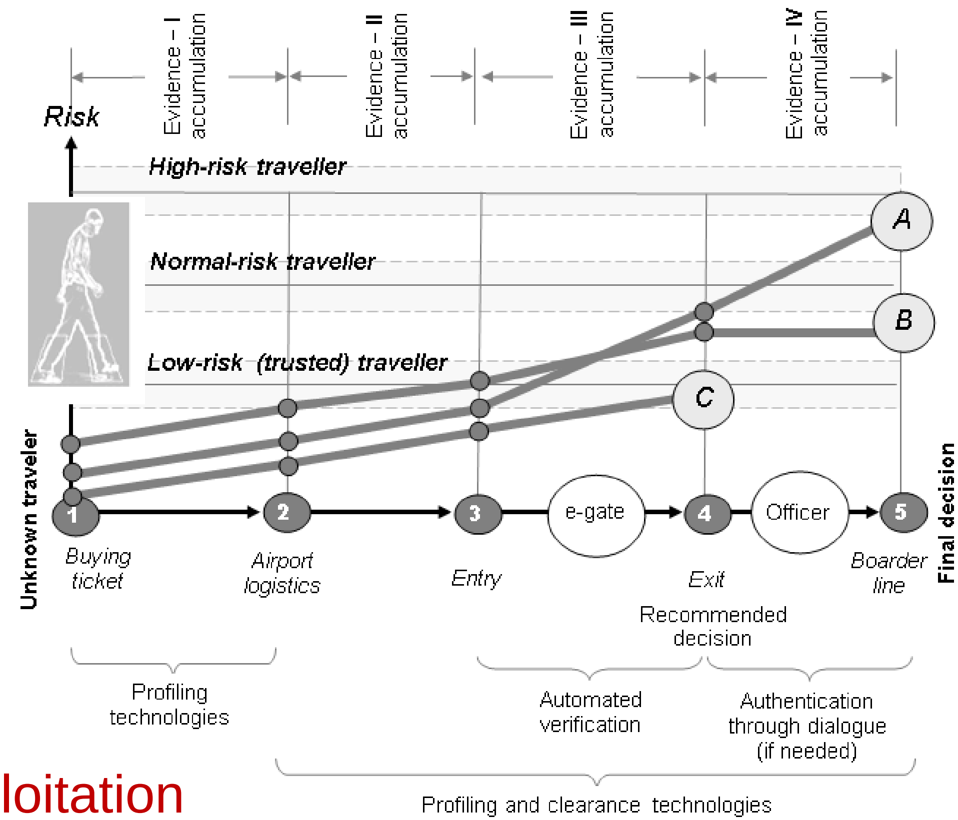
•*Property 6:* It is a machine that automatically <u>communicates across the data network with other ABC machines and eBorder components.</u>

NB: extends ABC from Point solution to Air Continuum solution.

Why such formalization ?

- It allows to define ABC as Evidence Accumulation machine

- It allows to profile and assess risks of present and future ABC systems through modeling, which can be used for:
  - Training
  - Cost-Benefit Analysis
  - Risk analysis and risk mitigation strategies
  - Performance evaluation



ABC Profiler:

- Methodology & software for predictive analysis of eBorder deployment and exploitation

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Conclusions

- Three generations of ABC established
- Taxonomy of the eBorder components developed
- Limitations of standard evaluation practices examined
- Two ways of describing the ABC performance proposed:
  - Degraded performance
  - Through modeling of ABC as an evidence accumulating machine of the *eBorder* process within *Air Traveller Continuum*
- Next steps:
  - Establish ABC model for each country's Air Traveller Continuum
  - Based thereon, develop and apply ABC Modeler (software and methodology) to analyse the risks and mitigation factors of ABC as part of the entire eBorder process

Acknowledgements:

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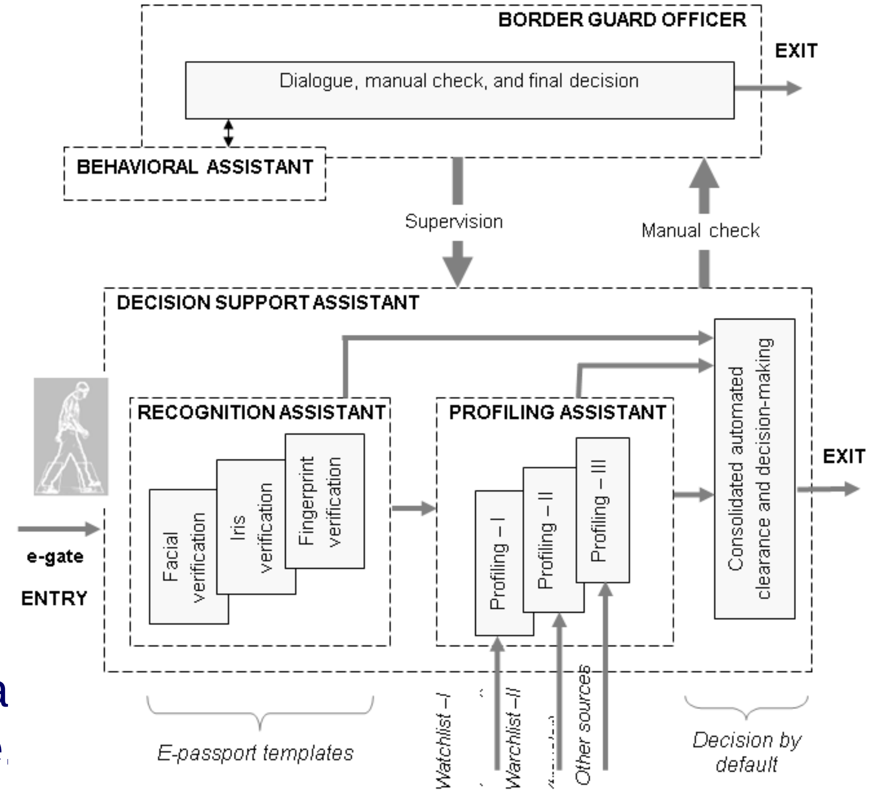
Supplement

Architecture of ABC machine

ABC machine is viewed as a decision support assistant which includes:

- *Traveller Authentication module:* "*recognition assistant*" performs identity verification using the biometric modalities specified by the e-passport,
- *Risk Assessment module:* *"profiling assistant"* performs profiling function using all available sources.

The reports provided by these assistants are processed using the principles of consolidated clearance and decision-making; the output is a recommendation, which is a final by default (ie. final unless overwritten by officer)



This corresponds to the semi- automated principle of the ABC machine. If a traveler has been directed to a manual check, the officer uses an interviewing technique which can be supported by a behaviour assistant .

Example: ABC Profiler for modeling Mantrap - 1

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Table 1. Library of modelling modules for authentication task.

	MODELING MODULE	STATE VARIABLES AND INITIAL DATA
1.	e-passport	Security features, chip-optical data crosscheck, watchlist, verification, manual check.
2.	Facial verification	Recognition, e-passport holder, number of attempts, watchlist, risk factor, manual check.
3.	Pre-screenin	Risk-factor, airport surveillance, API (advanced passenger information), watchlists.
4.	Pre-logistics	Signs, e-passport holder, surveillance, risk-factor, behavior (geography, ethnic) factor
5.	Manual check	Machine assistance, risk-factor, behavior factor, interviewing, decision support/making.
6.	Logistics attack	Topology, queuing, risk-factor, impostor/terrorist, behavior factor, surveillance.
7.	Mantrap attack	Single traveller detector, baggage detector, risk-factor, behavior factor, topology.
8.	Authentication attack	e-passport attack, plastic surgery, make-up detection, verification, manual check, risk-factor.
9.	Watchlists	Searching time, combined database, risk-factor, updating, manual check, decision-making.
10.	Training personnel	Personal skills degradation factor, decision-making/support, human-machine collaboration.

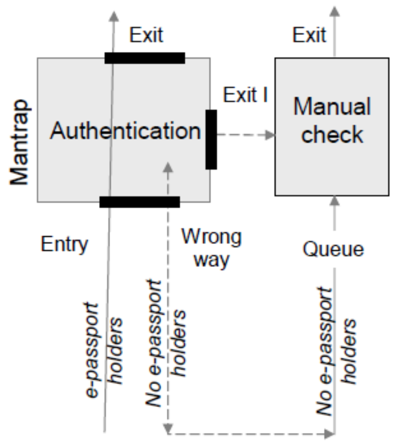

Figure 4. The mantrap structure with direct-reverse entry and two exits.

Example: ABC Profiler for modeling Mantrap - 2

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State variables. The Bayesian network of a simplified mantrap component of the ABC machine is given in Fig. 5.

The variables that are used in the network in Fig.5 are:

- $H \in \{h_1, h_2\}$, h_1 = yes, h_2 = no, denotes whether or not the customer is an e-passport holder.
- $A \in \{a_1, a_2, a_3, a_4\}$ represents a simplified authentication procedure that includes e-passport check, verification, and watchlist check: a_1, a_2, and a_3, correspond to the 1st, 2nd, and 3rd attempt, and a_4 denotes the authentication failure. Note if the traveller does not hold an e-passport ($H = h_2$), then the authentication will always fail ($A = a_4$).
- $M \in \{m_1, m_2\}$ denotes whether or not the traveller is redirected to the manual check, where m_1 = no dialogue with the border agent and m_2 = regular dialogue with the border agent. If a traveller does not hold an e-passport ($H = h_2$), or has failed authentication ($A = a_4$), then they are automatically subjected to a regular dialogue with the border agent ($M = m_2$).
- $E \in \{e_1, e_2\}$ denotes whether or not the traveller is authorized, e_1 = successful exit, e_2 = blocked by security. Any traveller that has been exempt from dialogue with a border agent ($M = m_1$) is automatically cleared to leave the crossing ($E = e_1$).
- $W \in \{w_1, w_2, w_3\}$ denotes the wait time for the traveller, w_1 = a wait time is less than 10 min, w_2 = a wait time of more than 10 min, and w_3 = no authorization given during an allowed attempt time. A traveller waits ($W = w_3$) if he/she failed to cross the border ($E = e_2$).

The joint probability distribution for the Bayesian network is: $P(H, A, M, E, W) = P(H) \times P(A|H) \times P(M|H, A) \times P(E|A, M) \times P(W|M, E)$.

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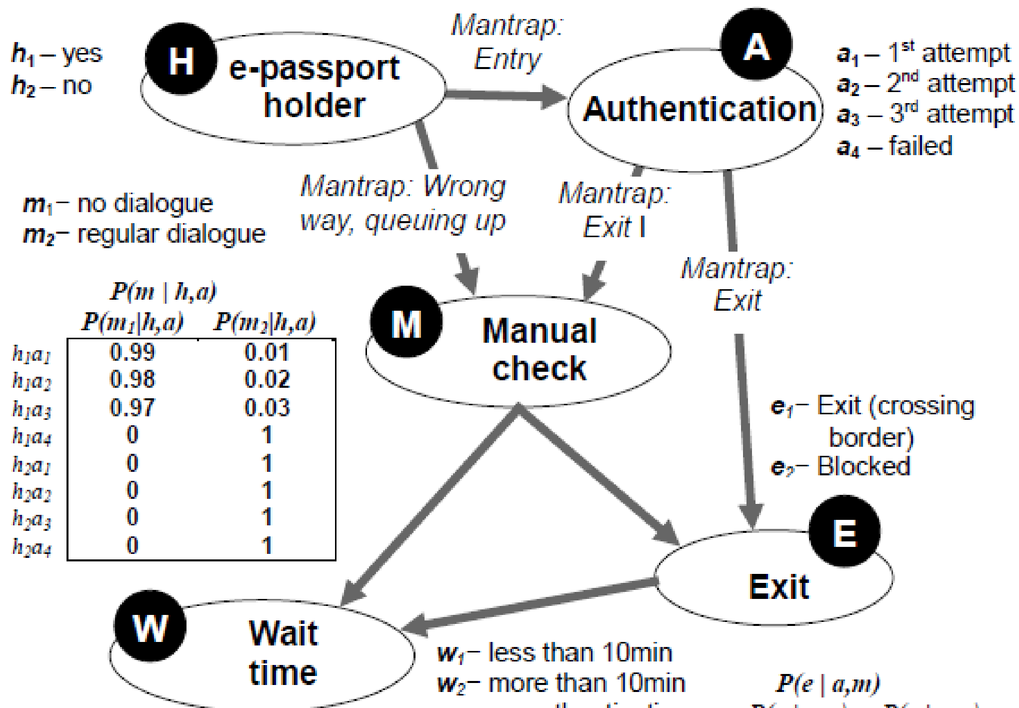

$P(h)$

$P(h_1)$	$P(h_2)$
0.98	0.02

$P(v \mid h)$

	$P(a_1\|h)$	$P(a_2\|h)$	$P(a_3\|h)$	$P(a_4\|h)$
h_1	0.70	0.15	0.05	0.10
h_2	0	0	0	1

$P(m \mid h,a)$

	$P(m_1\|h,a)$	$P(m_2\|h,a)$
h_1a_1	0.99	0.01
h_1a_2	0.98	0.02
h_1a_3	0.97	0.03
h_1a_4	0	1
h_2a_1	0	1
h_2a_2	0	1
h_2a_3	0	1
h_2a_4	0	1

$P(e \mid a,m)$

	$P(e_1\|a,m)$	$P(e_2\|a,m)$
a_1m_1	1	0
a_1m_2	0.999	0.001
a_2m_1	1	0
a_2m_2	0.998	0.002
a_3m_1	1	0
a_3m_2	0.997	0.003
a_4m_1	1	0
a_4m_2	0.6	0.4

$P(w \mid m,e)$

	$P(w_1\|m,e)$	$P(w_2\|m,e)$	$P(w_3\|m,e)$
m_1e_1	0.9	0.1	0
m_1e_2	0	0	1
m_2e_1	0.4	0.6	0
m_2e_2	0	0	1

Figure 5. A simplified Bayesian network that models the mantrap component of an ABC machine. The conditional probabilities here were chosen reasonably closed to the reported border crossing statistics.

Example: ABC Profiler for modeling Mantrap -3

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is authorized at the first attempt. Specifically, the risk (measured in a probabilistic metric) that the e-passport holder is waiting for more than 10 min ($W = w_1$) after the first ($A = a_1$), the second ($A = a_2$), and the third ($A = a_3$) attempt is $\texttt{Risk}(w_1|h_1, a_1) = 1 - p(w_1|h_1, a_1) = 1 - 0.895 = 0.105$,
$\texttt{Risk}(w_1|h_1, a_2) = 1 - p(w_1|h_1, a_2) = 1 - 0.890 = 0.110$,
$\texttt{Risk}(w_1|h_1, a_3) = 1 - p(w_1|h_1, a_3) = 1 - 0.885 = 0.115$,
respectively. The risk of waiting for more than 10 min, if the automated authentication failed, increases significantly:
$\texttt{Risk}(w_1|h_1, a_4) = 1 - p(w_1|h_1, a_4) = 1 - 0.2400 = 0.760$.

Table 2. Risks of border crossing wait time > 10 minutes using ABC machine after the traveller's first, second, and third attempt to interact with authentication devices, as well as failed all three attempts.

Authentication attempt	1st	2nd	3rd	Failed
Risk (probability) of border crossing wait time $>$ 10 minutes	0.105	0.110	0.115	0.760