Un modèle graphique basé sur les facteurs affectant la performance pour l'évaluation de la fiabilité humaine

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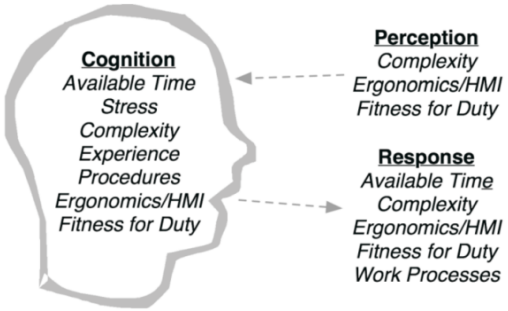
Introduction

- **Human reliability analysis (HRA)**
  - Identifying, analyzing (qualitative, quantitative) and integrating human in risk analysis
  - Causes and consequences of human failures
  - Origins in the nuclear domain, adapted to other (aviation, petroleum, healthcare…)
- Why
  - ‘Human error’: a safety imperative
  - Railway operations – a complex sociotechnical system
  - HRA methods used in railway (EU) – very few or none at all (a European Union Agency for Railways study)
- This work
  - Towards quantitative HRA for railway application

Positioning

Some more common HRA concepts:

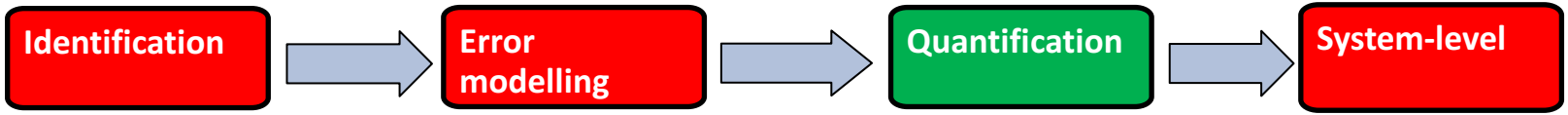
- HFE (Human Failure Event)
  - Basic event - a possible human error
- PSFs (Performance Shaping Factors)
  - To identify contributors which increase or decrease likelihood of human error
- HEP (Human error probability)
  - Given the PSF(s) and their states, probability of an HFE
  - Newer 2nd generation narrative – context important (more than quantification)



SPAR-H's PSFs [Blackman et al., 2008]

3. Probabilistic graphical model-based

- No complete methodology yet, a mathematical framework
- Can use different types and sources of data
- Different types of frameworks – Bayesian networks and belief functions
- Steps -
  - Step-2 – Define *relation between the variables* – affect of PSF (or PSF--PSF)
  - Step-3 – Input data for quantification (*data on the state of PSFs needed to quantify HFE*)
  - Step-4 – HFE quantification and sensitivity analysis



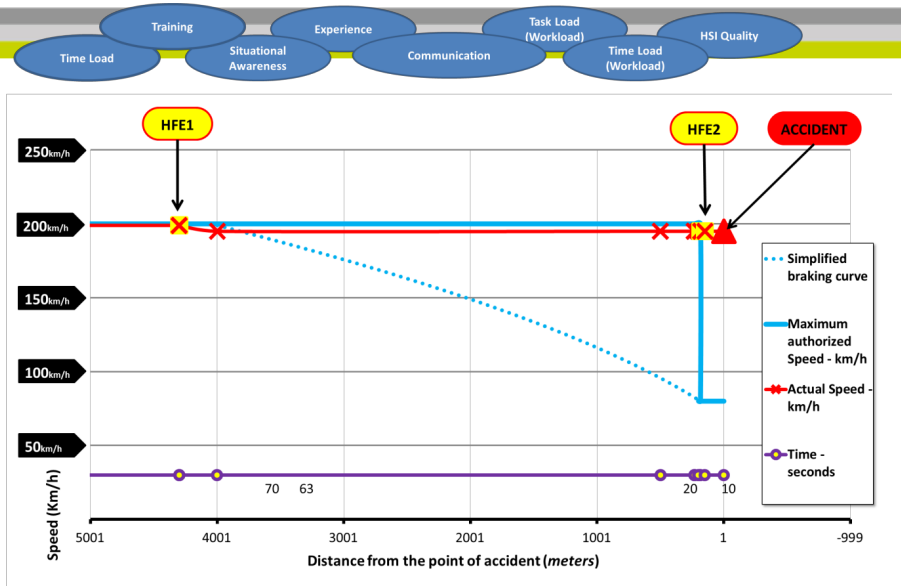
Some challenges towards quantification

- For the railway domain: more work to align HRA with existing practices (human factors and risk analysis)
- Off-the-shelf use of a HRA methodology difficult
- A generic application (railway – actors, technologies, etc.)
- Need of complete methodology -- qualitative + quantitative
- Treatment of data
  - Complexity of quantification
  - Need of a formal methodology for error modelling
- Verification and validation of quantification

Accident scenario

Accident scenario timeline

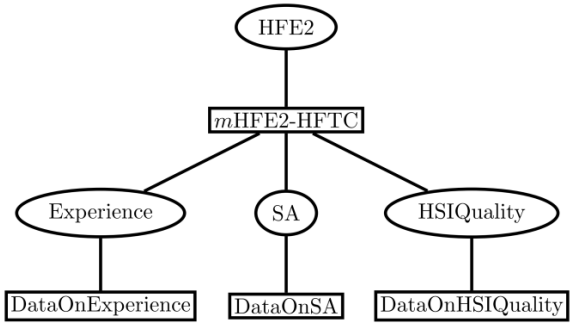
- PSFs list for railways – [Rangra et al., 2015b] , [Kyriakidis, 2013]
- Retrospective analysis
  - HFE's – from accident investigation report
  - Only immediate HFEs



TASK: Respecting track speed limits – Approaching a section of track with reduced speed limits (absence of automatic protection)	
	PROCEDURE
HFE1. Not reducing speed in time	National regulations – "any agent, regardless of its function, is passive and immediate obedience to signals concerning...". "The driver shall endeavor to recognize the signs (signals) as far as possible and do not lose interest in their observation as (long as) it (train) has not crossed them". "…driver should identify the reference (point) to initiate the braking and to reduce the speed…"
HFE2. Not respecting the speed signals (in schedule book/ table of speeds)	"Maximum speed change indicates the point on the line (where) changes in the maximum speed allowable by infrastructure, (are present) as established in the tables of maximum speeds." National regulations – "Goal: change of maximum speed...driver should respect absolutely the speed limits (as) mentioned in train schedule book or signal on the track side."

3. Belief network-based

- Possibility of integrated error modeling and quantification
- Can start with complete absence of predefined values (re-use possible)
- Different frameworks mainly belief functions and Bayesian networks
- Steps of application
  - Step-1 – Qualitative identification of HFEs and PSFs
  - Step-2 – Relational data (define configuration/CPT)
  - Step-3 – Input data for quantification (direct evidence)
  - Step-4 – Quantification results and sensitivity analysis



Identification
- Step-3

- Step-1 – NA (either use from other HRA model or Analyst), ATHEANA-like approach can be undertaken

Error modelling
- Step-2

- Step-2 – Quantitative relational data form Experts OR empirical sources OR pre-defined

Quantification
- Step-3
- Step-4

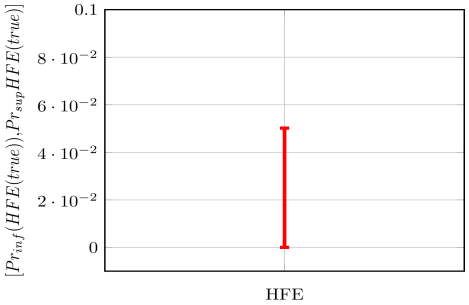
- Step-3 –Analyst (needs data only on PSFs, not on the relations, no analyst subjectivity in model)
- Step-4 – Analyst

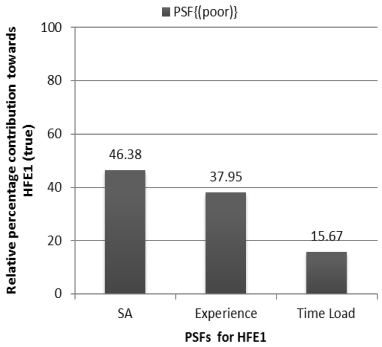
System-level
- NA (Integration in a PRA)

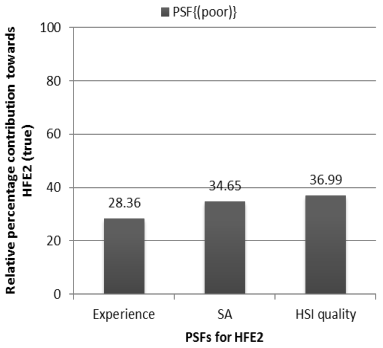
- NA – follow guidelines of PRA

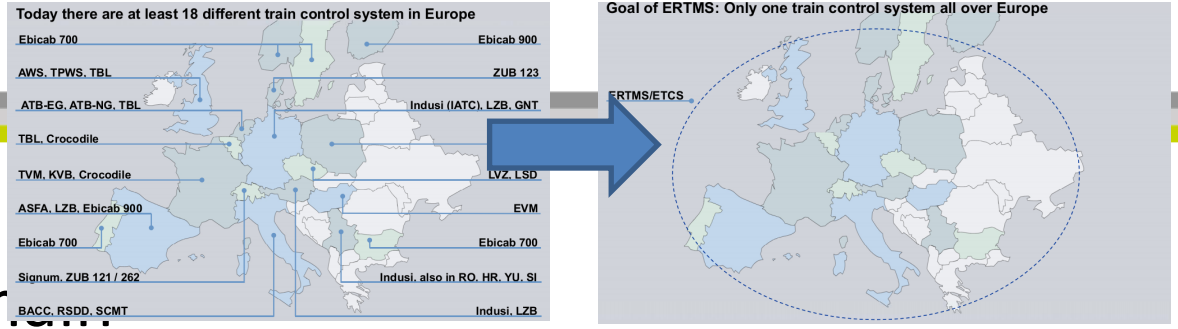
Example quantification…

- Step-4 – Quantification results and sensitivity analysis
  - Quantification results (interval represents ‘epistemic’ – i.e. uncertainty in model)
    - “A probability interval of occurrence of an HFE (an HEP)” e.g. [0.0005, 0.005]
  - Sensitivity analysis results – priority rankings amongst PSFs
  - “priority focus should be on improving aspects of HSI quality and Situational Awareness”



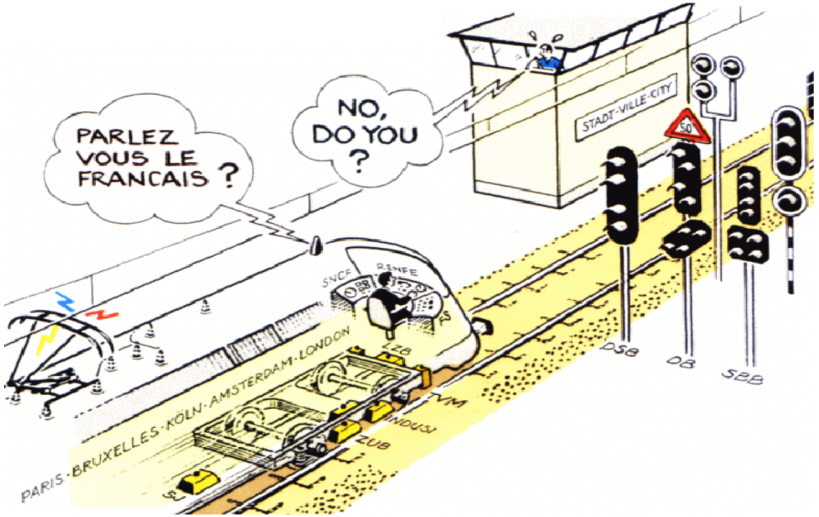






– Application dom...

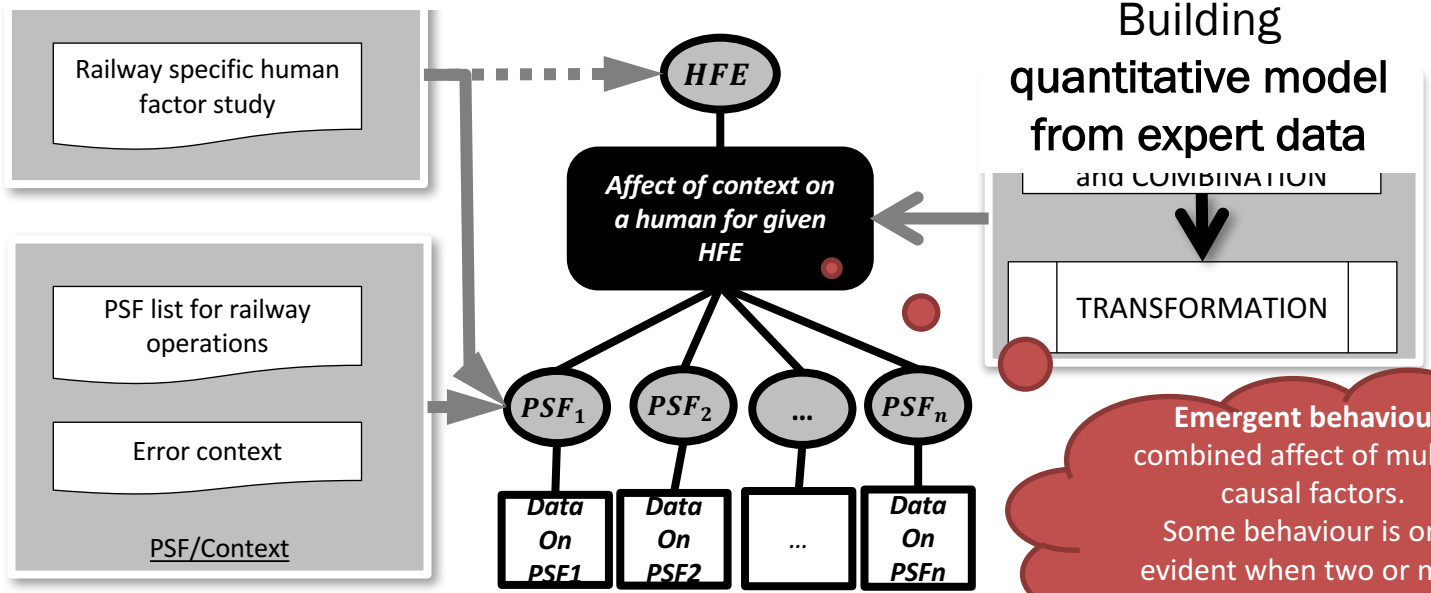
- ERTMS – European Railway Traffic Management System
- **Railway operations**: high reliability requirements
- **Unified**: new challenges of a complex sociotechnical system



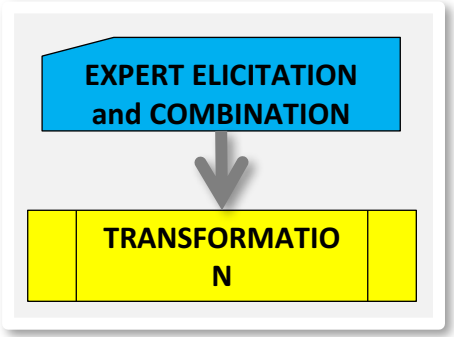
2. PRELUDE: A complete HRA methodology

Performance shaping factor centered decision support for human Reliability assEssment using vaLUation-baseD systEms

What is the human supposed to do (**Human Failure events - HFEs**) and in what context (**Performance Shaping Factors - PSFs**) ?



2.1 Quantitative HRA model: from expert data



A HFE and an context PSFs (Communication, Task Load, Time Load)

QUESTION: **one question per PSF and HFE**	Response (on a probability scale)
Question *1*. Given a ***poor*** level of ***Communication*** what do you think about ***HFE*** being ***true***?	0.05
Question *2*. Given a ***poor*** level of ***Task Load*** what do you think about ***HFE*** being ***true***?	…
Question *n*….	0.95

- Combination of data **for each question** (multiple experts) Average, Weighted average, vote. Dempster's rule, Yager's rule

A conditional piece of evidence on states of a PSF for given states of HFE

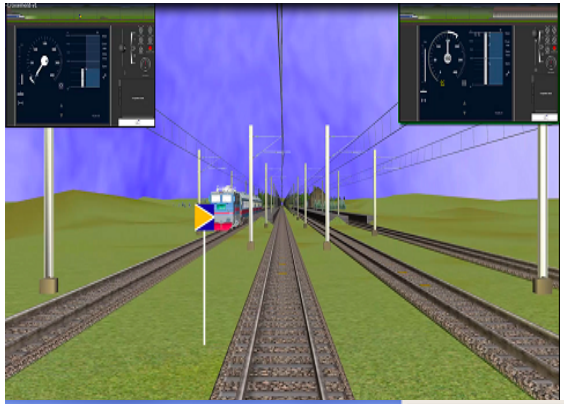
- Second combination: Combine information from all the questions

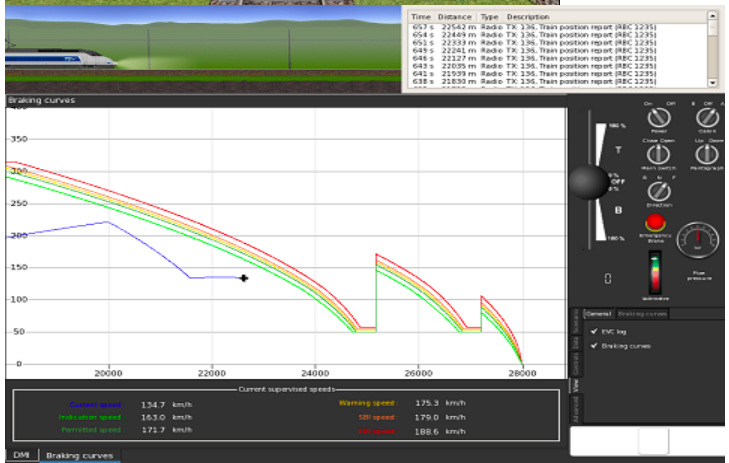
Valuations formally defining relation between states of an HFE and states of the context (PSFs)

Quantitative HRA

- From expert data to experimental data…

The train driving simulator

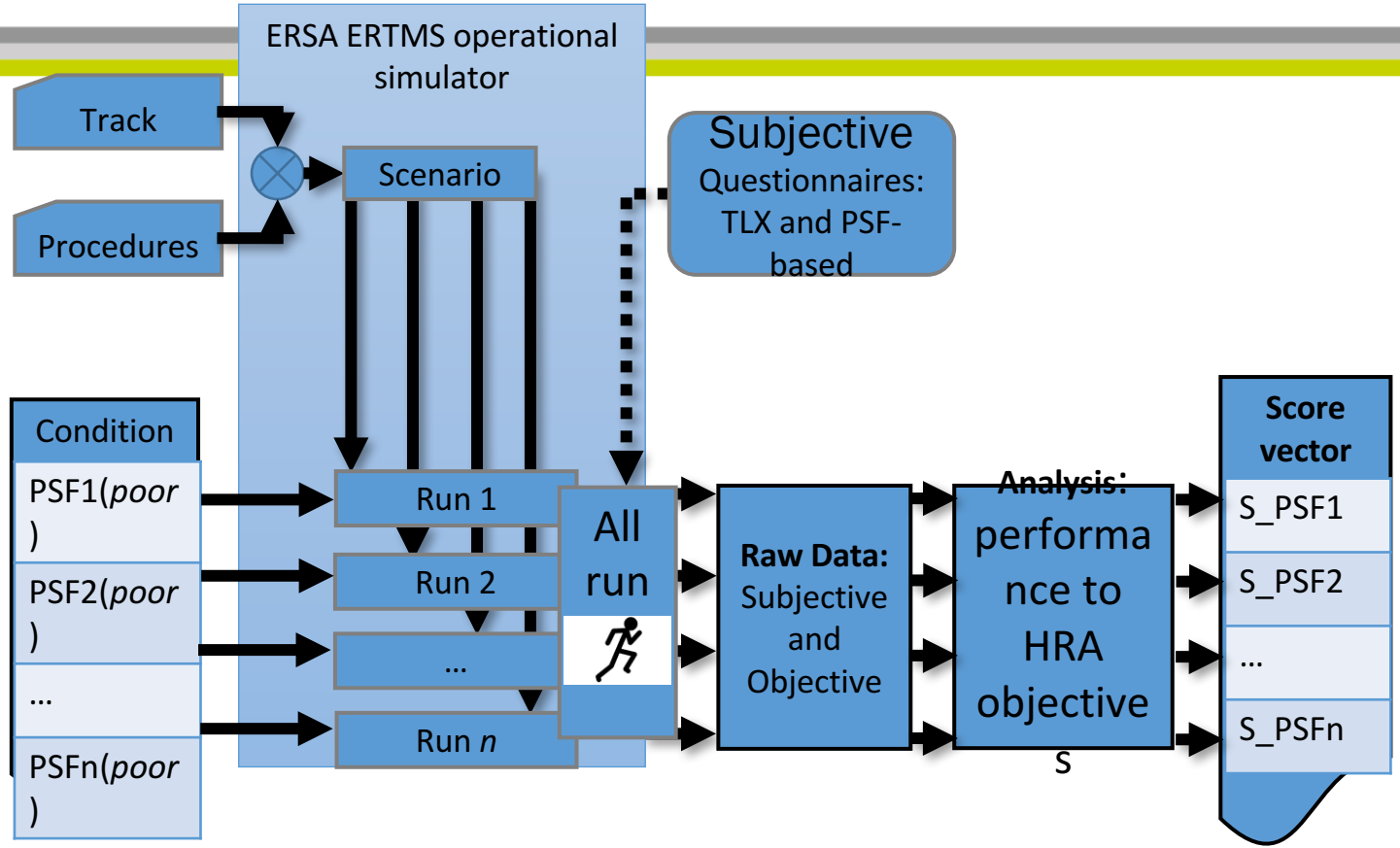




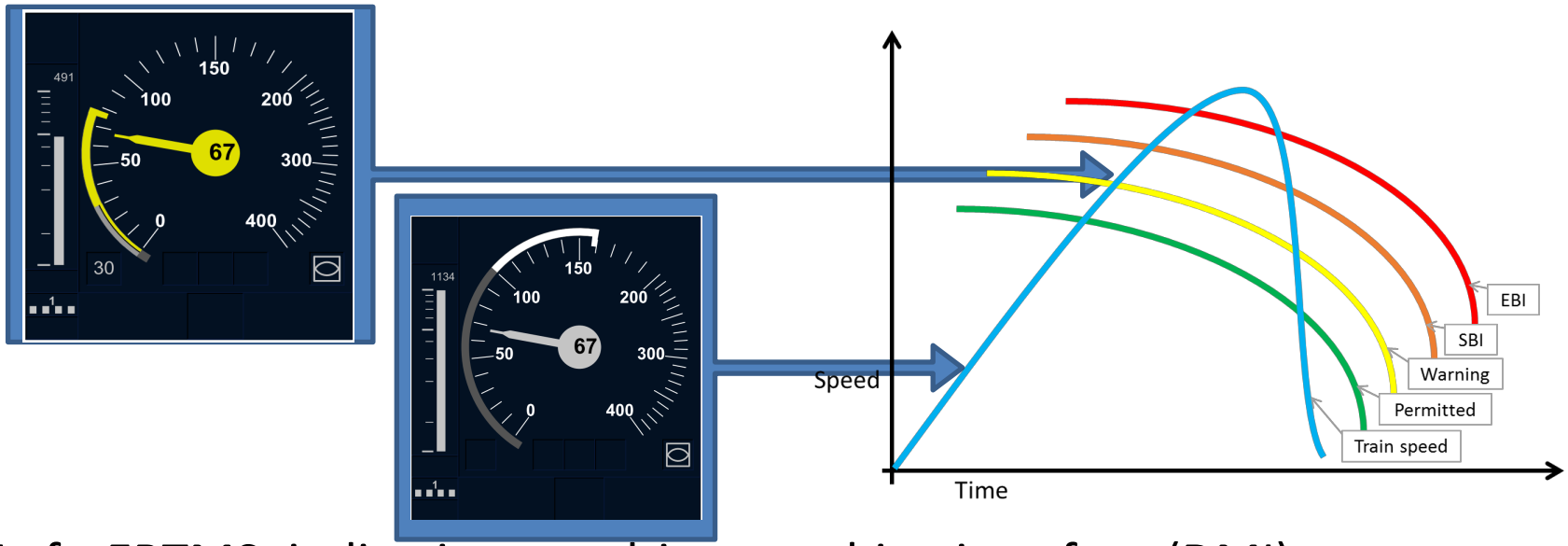
3. Simulator protocol: Objectives

- A set of objectives for expected performance:
  - Ensure safety: observe speed limits, marker boards, etc.
  - Ensure on-time service vs. given timetable
  - Respect standard operating procedures
- A set of conditions
  - Poor Training/Experience; poor Situational awareness (SA)…
- Analysis objective: performance evaluation criteria

3. Simulator protocol: Overview



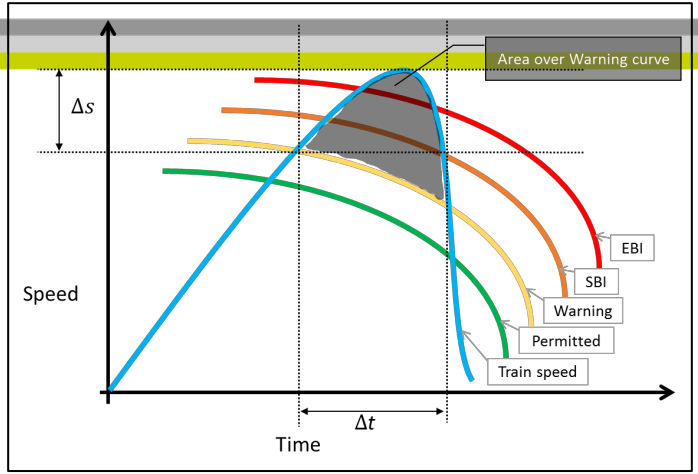
3.1 Analysis: Objective data



- Left: ERTMS: indications on driver machine interface (DMI)
- Right: Speed curves generated for the automatic train protection (ATP) automatically by on-board system – for the scenario

3.1. Analysis: Score vector…

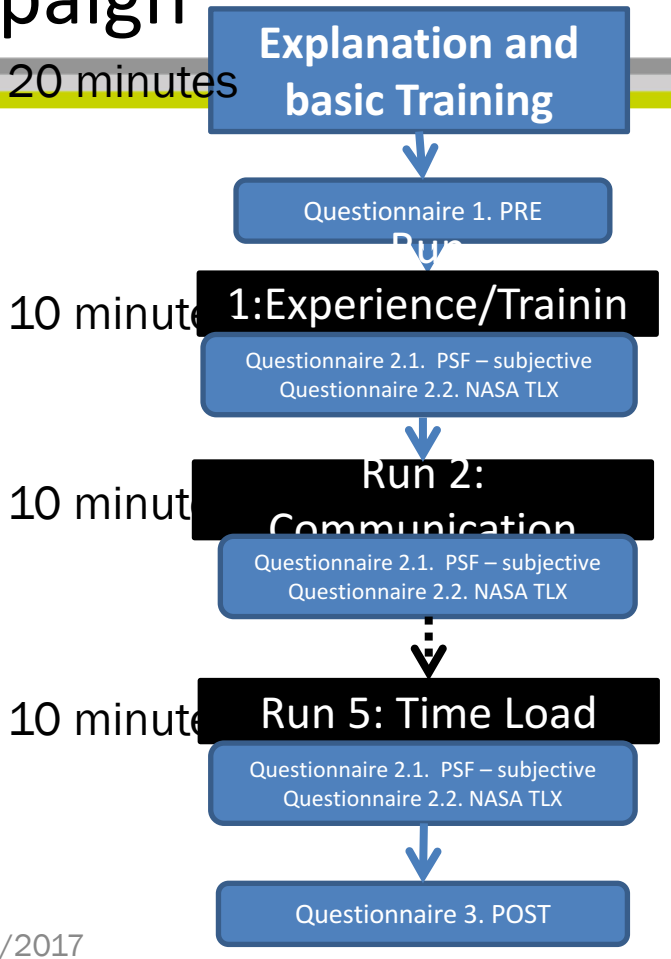
- A metric of negative ‘Evolutionary behaviour’
  - Interpreted as absolute score for a run
- Score vector:
  - Safety component: ***Safety Score***
  - Service component: ***Time Score***
- ***Safety score***: difference between speed limit (for all curves) vs. train speed
- ***Time Score***: difference between total time (in the timetable) vs. the time taken.



Safety Score: computation from speed curve score – for warning curve

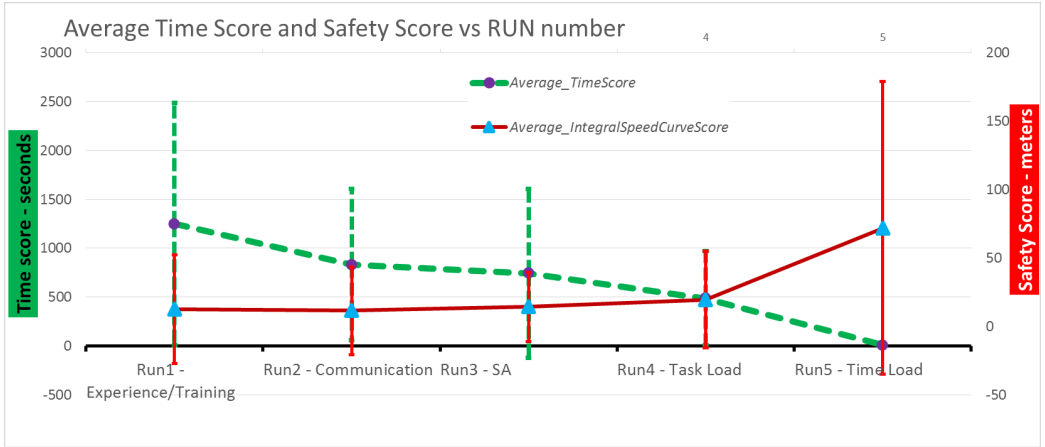
3.2. The campaign

- 13 volunteer subjects
- A complete session for a subject lasted about 2 hours



3.3. Results

- Average safety score vs time score for runs:
  - Run 5 – worst safety performance and best on-time service
- Time score vs Safety score:
  - Emergent behaviour ***polymorphism* – error or no error**
  - over speeding is dangerous behaviour; but tolerated (to am limit) – since arrival on-time sometimes more important!



3.3. Results…

- Averages: loss of a critical understanding of contextual affects and performance/behaviour
- Difference in scores:
  - A difference in understanding of the objectives *or* performance
- Groups of subjects based on scores (Safety score) : ‘good’ / ’average ’/’ bad’ performance…
  - *Group 1* - Mean scores of all of their runs **less than 10**
  - *Group 2* - Mean scores of all of their runs **between 10 to 50**
  - *Group 3* - Mean scores of all of their runs **more than 50**

Human factors: Conclusions and perspectives

- Quantitative data to model human reliability requires ***quantity*** (**multiple sources)** and **careful analysis**
- **An integrated risk analysis methodology** for transportation – to better understand and reduce risk
- Link different types of data from different sources:
  - Experimentations – human performance (dynamic/evolving)
  - Conflict in expert data – data aggregation/combination rules
- Human and context – complex causal factors modeled
- Easy adaptation of present work's results: Operational simulator and standardized signalling system (ERTMS)

Thank you.
Questions?

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