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Assessing human performance and safety of railway operators: A Human Performance Railway Operational Index (HuPeROI) to enhance safety of railway operations

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Agenda

- Motivation - Aim of research
- Railway Performance Shaping Factors taxonomy (R-PSFs)
  - methodology, dependencies, most significant factors
- Human Performance Railway Operational Index (HuPeROI)
  - methodology, development, implementation, preliminary findings
- Results - Difficulties
- Conclusion - Future work

Motivation

US FRA safety data shows that train accidents due to human factors reach the last decade constantly more than 30% of total railroad accidents

Recent study (Evans, 2011) shows that the majority of fatal train accidents in Europe for the last 29 years were caused by:

1. SPADs
2. Excessive speed
3. Signaling or dispatching error

Motivation

Train collision, 1999

SPAD, Ladbroke Grove, U.K.

31 fatalities & 523 injuries

inadequate training, signal location

Motivation

Train collision, 1999
SPAD, Ladbroke Grove, U.K.

31 fatalities & 523 injuries
inadequate training, signal location

Train collision, 2008
SPAD, Chatsworth, L.A.

25 fatalities & 135 injuries
distraction, use mobile phone

Motivation

Lac-Mégantic, Quebec, **6 July 2013**
Train Derailment, 47 people dead, 2000 people forced from their homes

Aim of research

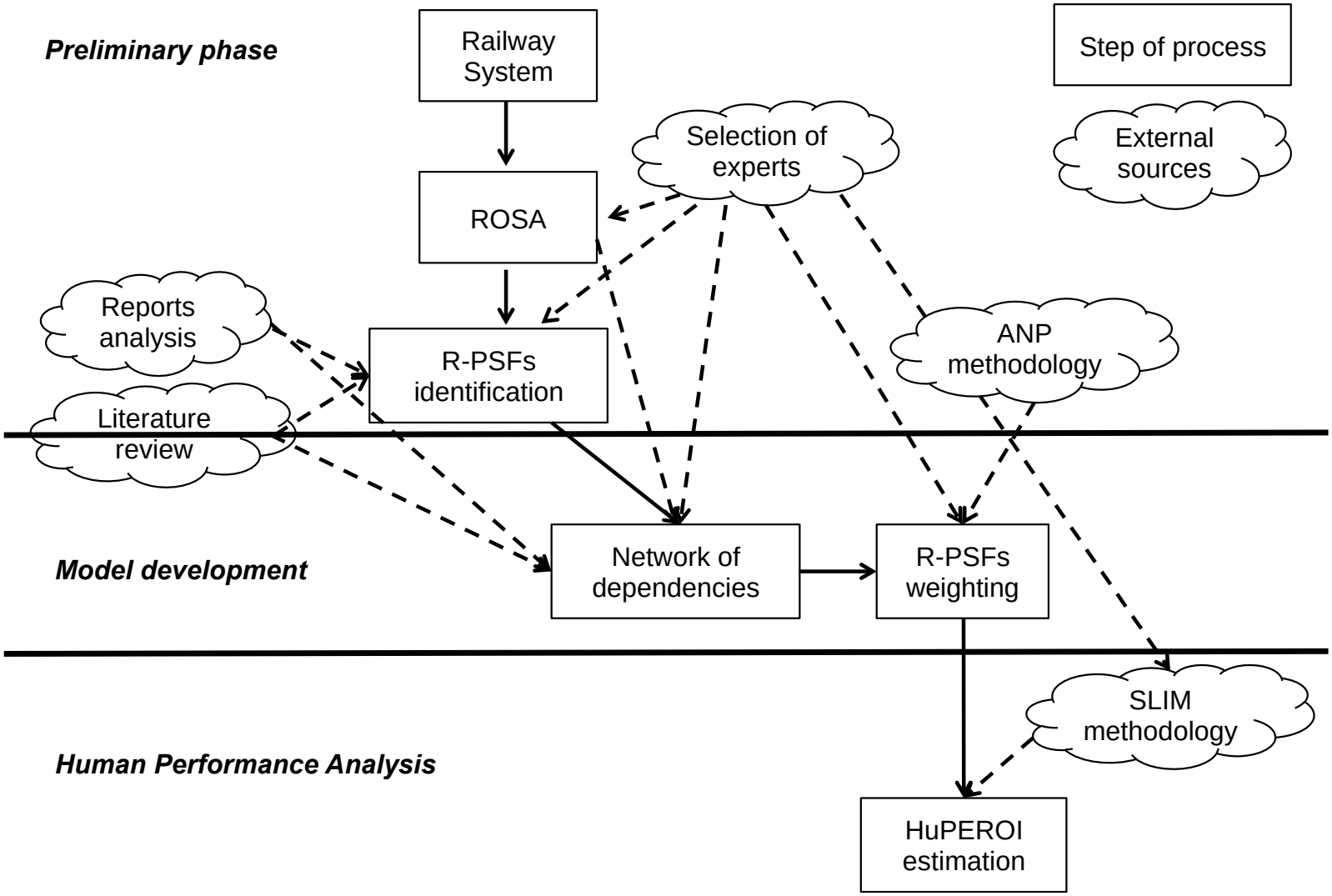
Develop an index, referred to as

Human Performance Railway Operational Index (HuPeROI)

which aims to:

- identify the factors that contribute and lead to human errors
- assess human performance
- provide insights for different employees "*perception*"
- direct resources more efficiently towards the development of sound solutions for improving operators performance

Framework of study



The modern railway system

The modern railway system

Based on the definitions from:

- EC Directive 2004/49/EC
- FRA Collision Hazard Analysis Guide
- Australian MoU between ATSB and Rail Safety Regulators

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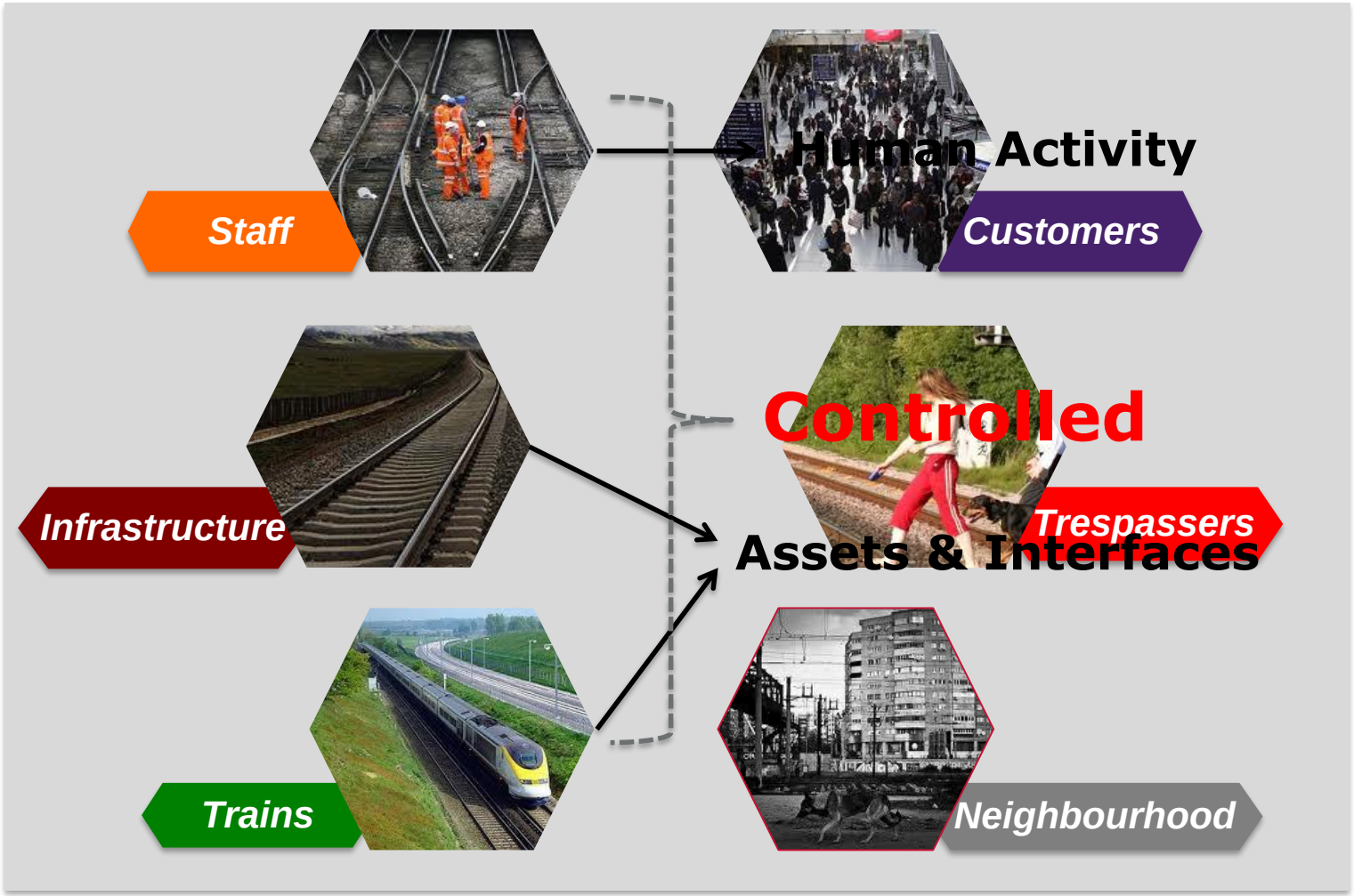
The modern railway system



The Railway Operational System Architecture (ROSA)

The ROSA

ROSA illustrates the interactions amongst the operators as well as amongst operators, infrastructure, rolling stock and other equipment

It has been developed based on:

- literature review (e.g. Bonnett, 2005, Burrage, 2003, Hall, 2005, RSSB, 2009)
- on-site visits, i.e. train driver cabins & railway control rooms
- targeted interviews with Subject Matter Experts (SMEs)

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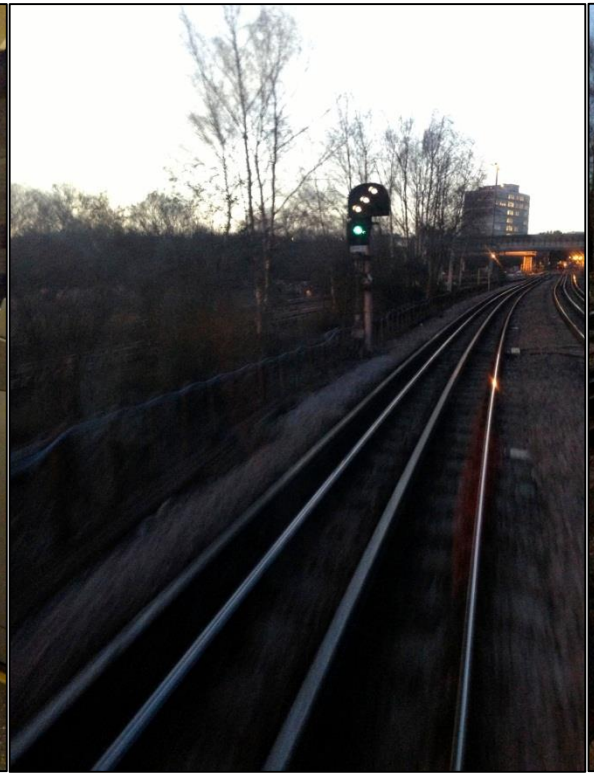
The ROSA

London Underground – Piccadilly line



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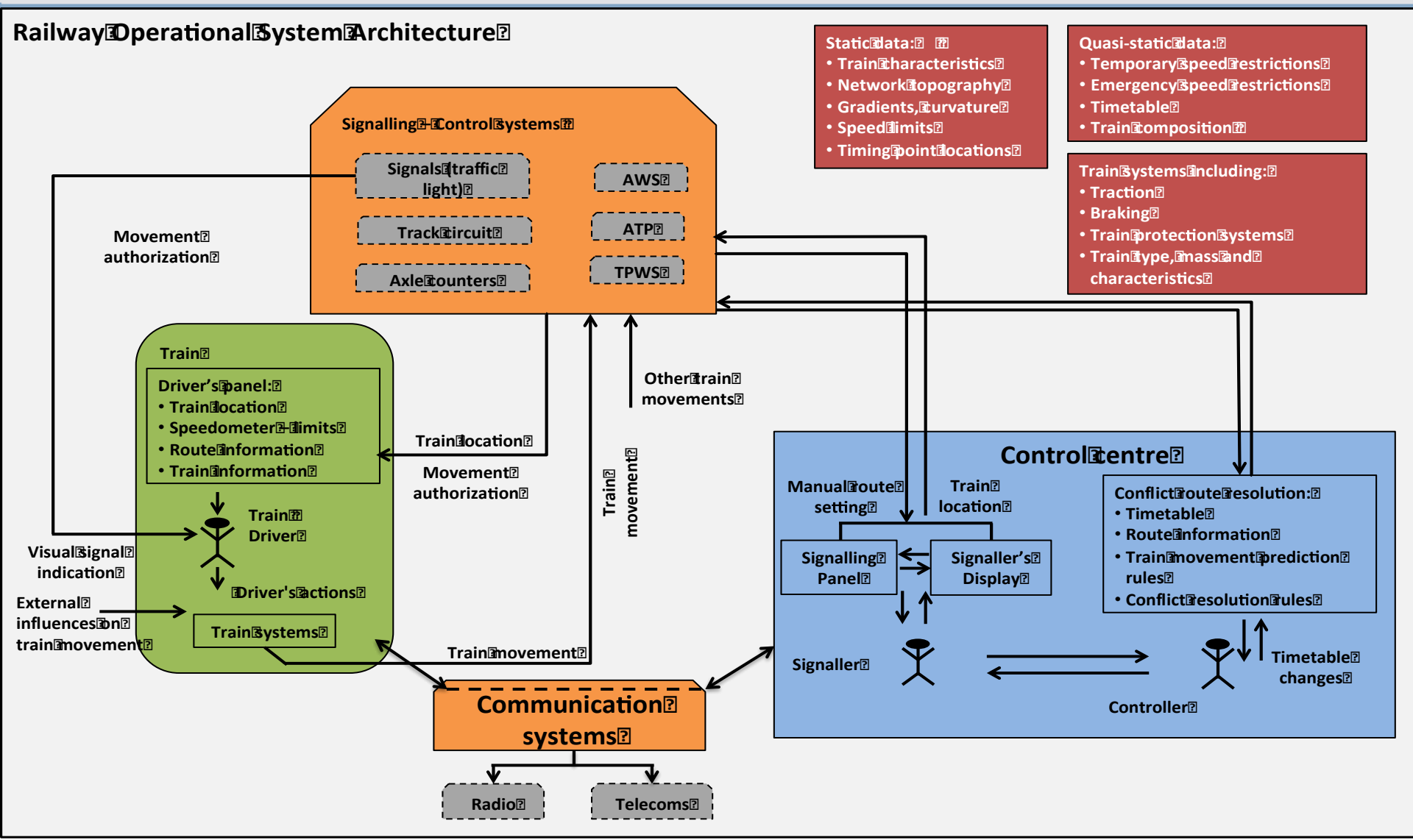
The ROSA



R-PSFs taxonomy

Performance Shaping Factors

PSFs can be described as:

"*all these factors such as age, working conditions, team collaboration, mental and physical health, work experience or training which enhance or degrade human performance*"

(Boring, 2007)

Human Performance

"the human capabilities and limitations that have an impact on the safety and efficiency of operations "

(Maurino,1998)

"the likelihood that a person will accomplish a given task under given conditions in a given time interval within the acceptance limits"

(Bubb, 2005)

Limitations of existing PSFs taxonomies

- Definitions of PSFs
- Dependencies amongst PSFs
- How each one of the PSFs affect on human performance

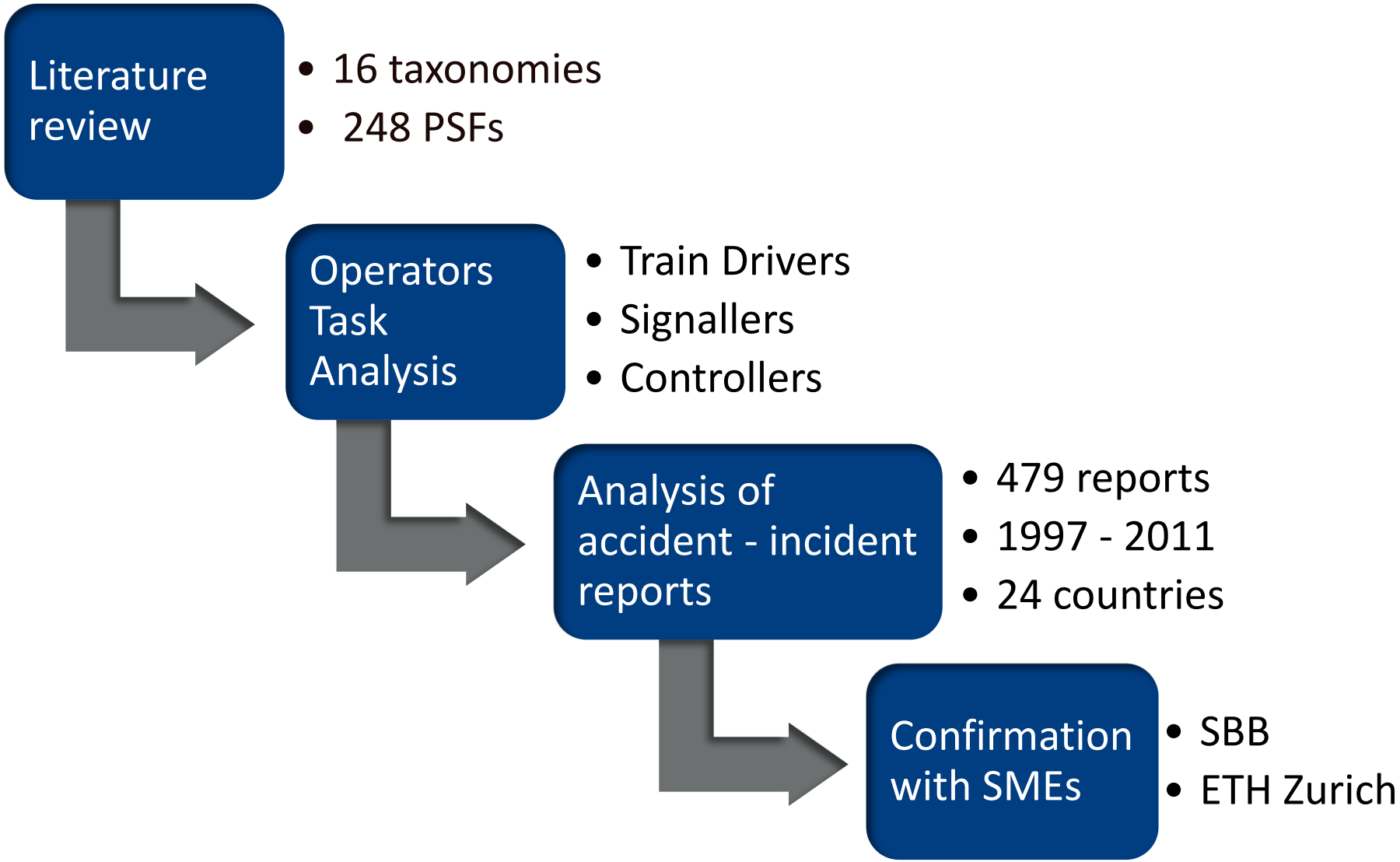
- Even taxonomies have been tailored to railway industry are developed on regional characteristics

Railway PSFs taxonomy - why a new approach ?

R-PSFs taxonomy:

- is developed based on the duties of railway employees
- clearly and precisely defines the PSFs - examples for railways
- distinguishes PSFs as dynamic and static
- Identifies dependencies between PSFs
- "weights" individual PSFs contribution to human performance

R-PSFs taxonomy development



R-PSFs taxonomy - Reports analysis

Reports contain information such as:

- Type of train
- Occurrence type
- Associated event
- Location and time
- Immediate cause
- Causal factors
- PSFs
- Consequences

R-PSFs taxonomy - Reports analysis

Occurrence type	Type of railway	Year	Month
Near miss		**2009**	**Ma**
Location		**Time**	**Responsibility**
Hanger Lane junction	London	**5:22 pm**	**Signaller,** Train dri
Description	**Immediate cause**	**Causal f**	**PSFs**
An eastbound District Line train 103 passed at signal WM1 at danger at low speed. The train stopped and the train driver reported the incident……to contact the train operator of train 103 once he became aware of the situation.	The signaler giving train 103 the authority to proceed towards Hanger Lane junction before it was safe to do so.	Train 103 S Signaller **did not bring all trains to a halt** Signaller was taking **prescribed medication**	**Time pressure** **Workload** **Communication**
Comments	**Consequences**		
Training inconsisten **Weather unlikely** to affect driver's visibility	uries or material		

HMI

HMI, Working conditions in the C.R.

Shift

Personal information

Stress

Dec.-mak. skills

Leadership, Saf. culture

Training

Experience

Fit to work

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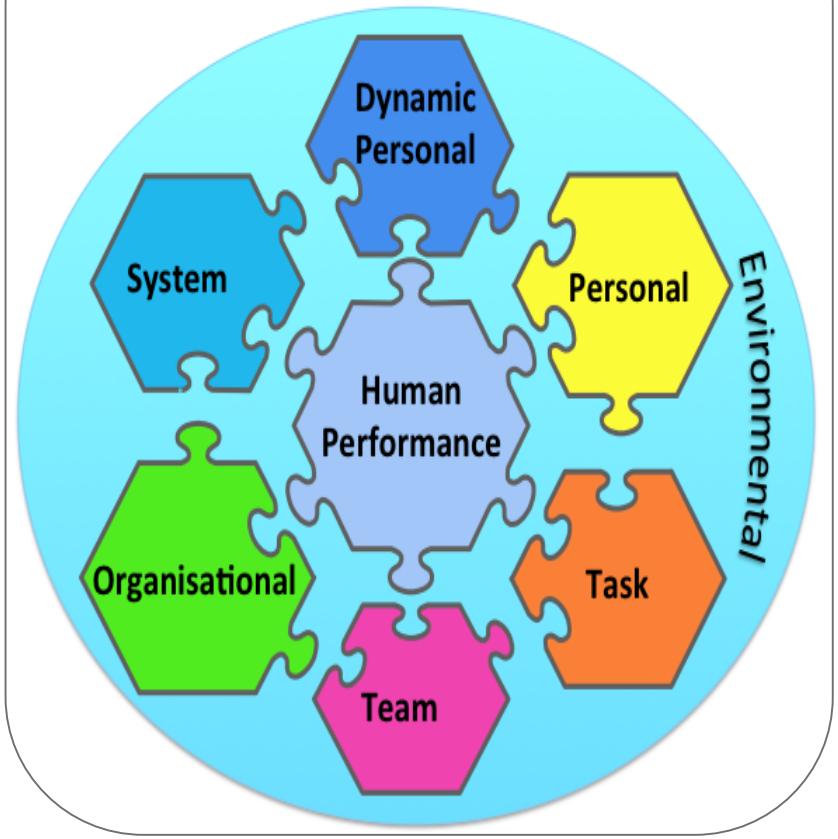
R-PSFs taxonomy development

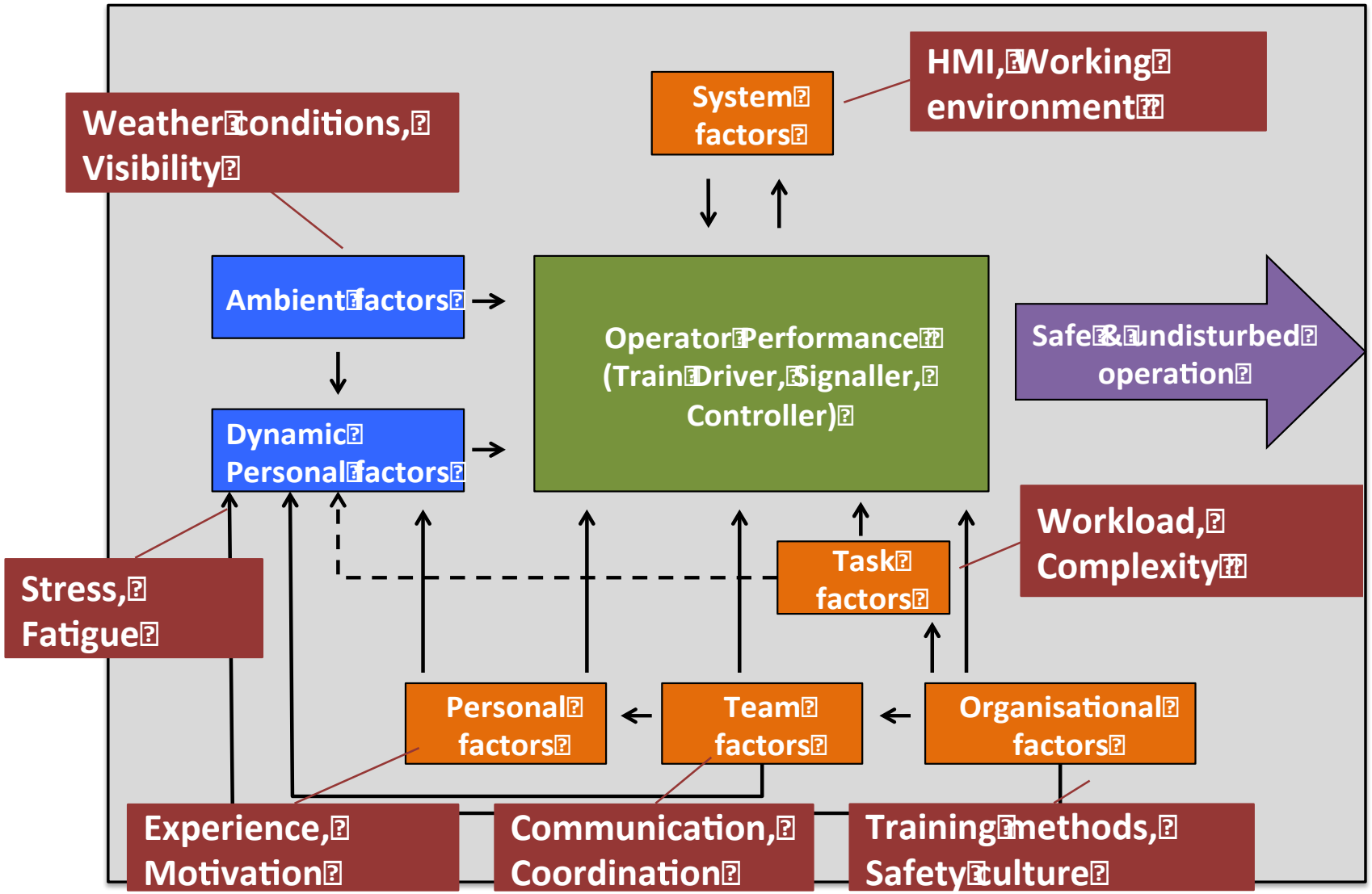
Development approach

1. Literature review → 16 existing taxonomies and 248 PSFs
2. Operators task analysis
3. Analysis of 479 worldwide incidents and accidents
4. Interviews with SMEs – *Swiss Federal Railways*

7 categories – 43 elements



R-PSFs taxonomy development



R-PSFs taxonomy - complete list

Personal	Dynamic Personal	Task	Team	Organisational	System	Environmental
Training - competence	Distraction - loss of concentration	Workload	Communication	Training / training methods	System design	Weather conditions
Fit to work (health)	Expectation	Monotony	Teamwork	Safety culture (disregard procedures)	Human Machine Interface	Visibility
Familiarity	Perception	Routine	Team relations	SMS	Working environment	
Experience	Interpretation	Time pressure - time to respond	Quality and trust in information	Quality of procedures, standards and regulations	Trust in equipment	
Motivation	Stress	Task complexity		Leadership	Railway communication systems	
Individual characteristics	Fatigue	Task instructions		Supervision		
	Vigilance			Shift pattern		
	Situational awareness			Relations within organisation		
	Decision making skills			Incentives for employees		
				Communication within organisation - feeling secure		
				Fit to work aspect		

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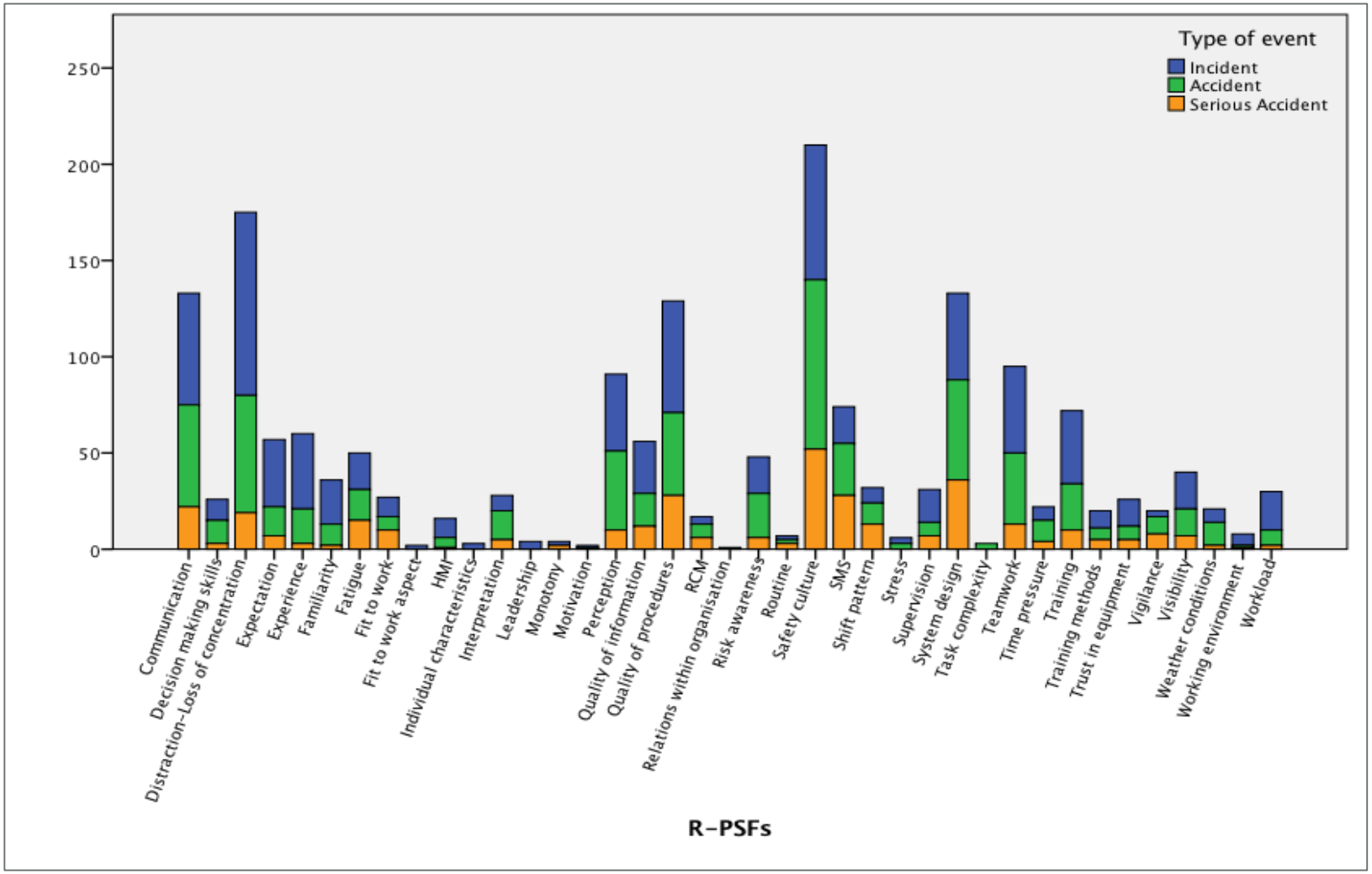
R-PSFs taxonomy - complete list



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R-PSFs dependencies - elements

Most frequent R-PSFs Direct influence →	Communication between driver - signaller	Coordination of work - Supervision	Distraction - Concentration	Expectation - Routine	Experience - Familiarity	Risk awareness	Fatigue	Fit to work - Health	Human Machine Interface	Perception	Procedures (disregard)	Procedures (inadequate)	Visibility	Stress	Time pressure - Time to respond	Training	Weather conditions	Workload
Communication between driver - signaller		✔ (a), (b)	✔ (a), (b)	✔ (a), (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (a), (b)	✔ (a), (b)	✔ (a), (b)	✔ (b)	✔ (a), (b)	✔ (a), (b)	✔ (a), (b)		✔ (a), (b)
Coordination of work - Supervision	✔ (a), (b)														✔ (a), (b)			✔ (b)
Distraction - Concentration	✔ (a), (b)														✔ (a), (b)			✔ (a), (b)
Expectation - Routine	✔ (a), (b)														✔ (a), (b)	✔ (a), (b)		✔ (b)
Experience - Familiarity	✔ (a), (b)														✔ (b)	✔ (a), (b)		✔ (b)
Risk awareness	✔ (b)														✔ (b)			✔ (b)
Fatigue	✔ (b)														✔ (b)			✔ (b)
Fit to work - Health	✔ (a), (b)														✔ (b)	✔ (a), (b)		✔ (b)
Human Machine Interface	✔ (a), (b)														✔ (b)	✔ (a), (b)		✔ (a), (b)
Perception	✔ (a), (b)														✔ (a), (b)	✔ (a), (b)		✔ (b)
Procedures (disregard)	✔ (a), (b)														✔ (a), (b)			✔ (b)
Procedures (inadequate)	✔ (a), (b)														✔ (b)	✔ (a)		✔ (b)
Visibility		(b)	(b)	(a), (b)		(b)	(b)			(b)	(a)			(b)	(b)			(b)
Stress	✔ (b)	✔ (b)	✔ (a), (b)	✔ (b)		✔ (b)	✔ (b)	✔ (b)		✔ (b)	✔ (a), (b)	✔ (b)			✔ (a), (b)			✔ (b)
Time pressure - Time to respond	✔ (a), (b)	✔ (a), (b)	✔ (a), (b)	✔ (a), (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (a), (b)	✔ (a), (b)	✔ (b)		✔ (a), (b)		✔ (a)		✔ (b)
Training	✔ (a), (b)	✔ (b)	✔ (b)	✔ (a), (b)	✔ (a), (b)	✔ (b)	✔ (b)		✔ (b)	✔ (a), (b)	✔ (b)	✔ (a), (b)		✔ (b)	✔ (a), (b)			✔ (a), (b)
Weather conditions	✔ (b)	✔ (a), (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)		✔ (a), (b)	✔ (a), (b)	✔ (b)	✔ (a), (b)	✔ (b)	✔ (b)			✔ (b)
Workload	✔ (a), (b)	✔ (b)	✔ (a), (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)	✔ (b)		✔ (b)	✔ (b)			

Direct influence → Perception

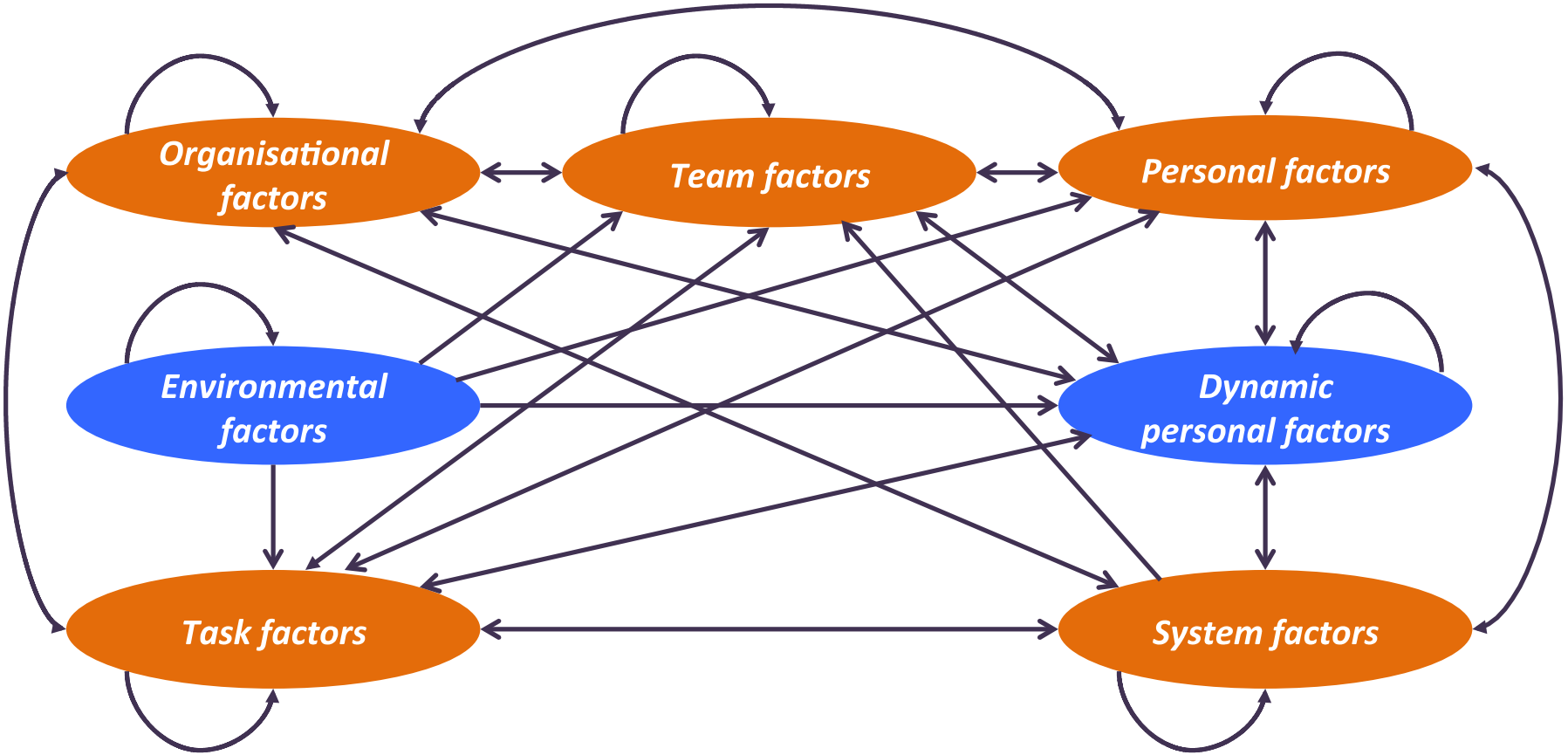
Fatigue ✓ (a), (b)

Stress ✓ (b)

(a): reports

(b): SBB employees

R-PSFs dependencies - categories



R-PSFs - 12 factors version

- Factors not identified equally to railway occurrences
- 43 factors difficult to further analysed

- Based on given definitions and sessions with experts
  - RSSB, HFs group
  - OWT, ETH Zurich

- R-PSFs version with 12 factors – which 12, why 12?
  - Findings from reports and ranking from SBB experts
  - Severity of consequences (human loses, financial loses)

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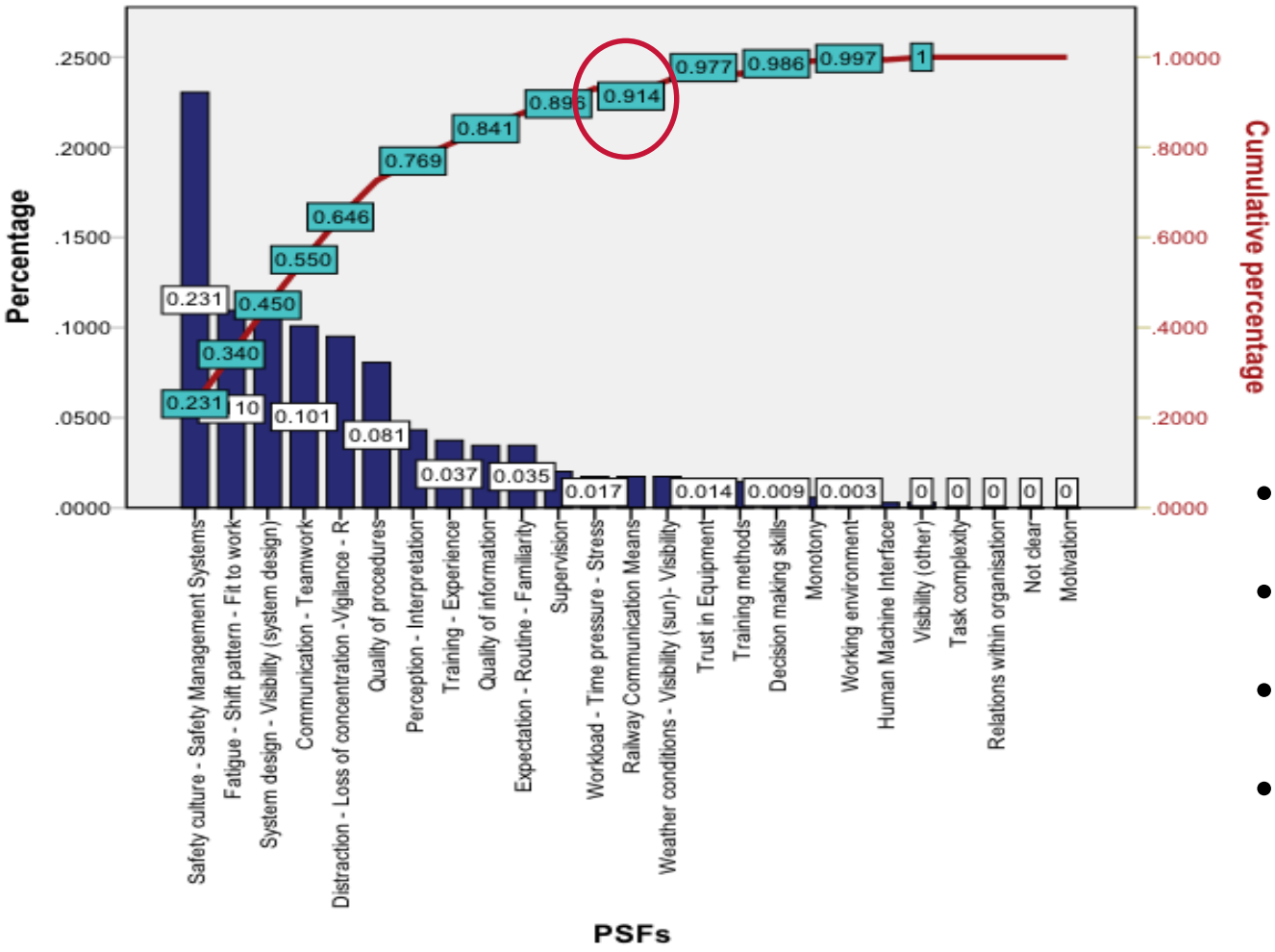
R-PSFs - 12 factors version



- Incidents
- Same 12 R-PSFs
- No fatalities
- Material damages at least of 2,000,000 €

Accidents

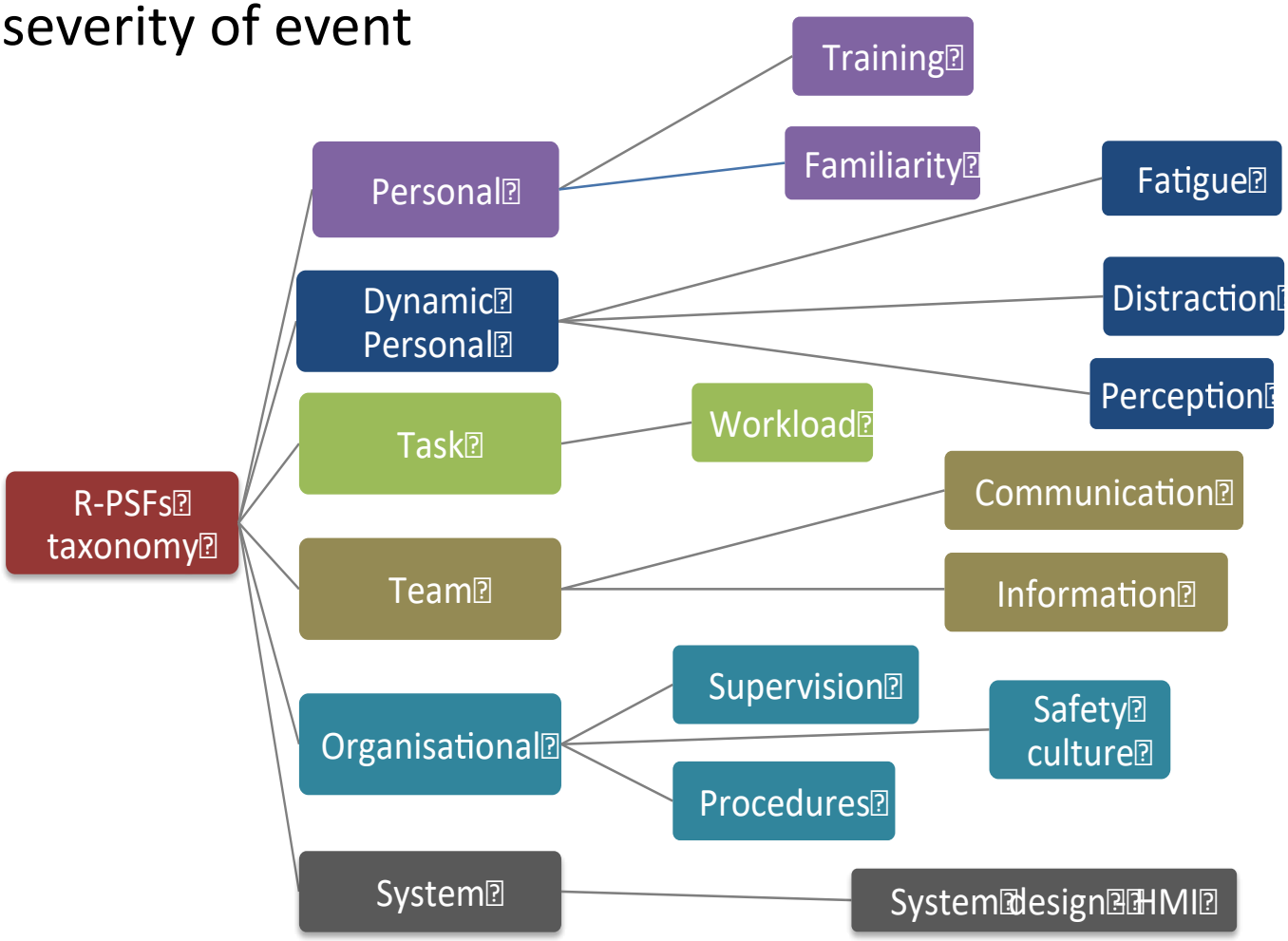
1 or 5

erious injured

/aterial damages less than 275.000 €

R-PSFs - 12 factors

…account for more than 90% of occurrences regardless severity of event

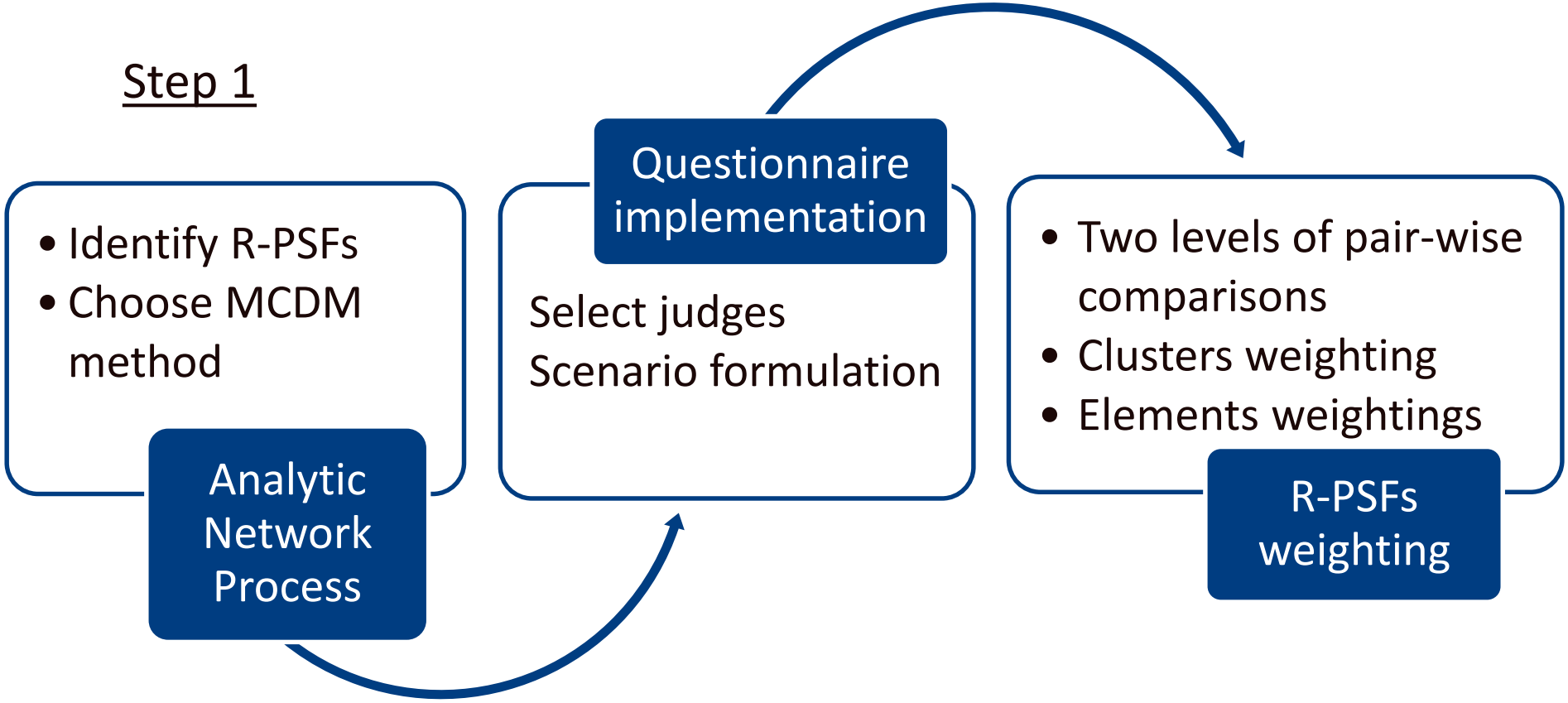


The HuPeROI

R-PSFs quantification

- Considers dependencies amongst:
  - R-PSFs categories
  - R-PSFs elements
- Analytic Network Process (ANP) methodology
- Success Likelihood Index Methodology (SLIM)
- R-PSFs pairwise comparisons for both levels
- 18 matrices to assess R-PSFs
- 54 participants → 972 collected matrices

HuPeROI development



HuPeROI development

Step 2

- Identify HEs for scenario

R-PSFs rating

HuPeROI

Optimal - suboptimal R-PSFs for scenarios

$$HuPeROI = \sum_{i=1}^{n} w_i \times r_{ij}$$

- Assess performance

Comparison of errors likelihoods

w_i, final weight of the i-th R-PSF

r_{ij}, i-th R-PSFs rating for the specific HE

R-PSFs quantification - "A SPAD" case study

"A SPAD" scenario: *Train Driver fails to stop at signal*

Question:

"Of the two categories which one is more and how much more important with respect to the influence on personal category?"

Personal	Extreme		Very strong		Strong		Moderate		Equal		Moderate		Strong		Very strong		Extreme		Personal
Dynamic Personal	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Organisational
Dynamic personal	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Personal

R-PSFs quantification - "A SPAD" case study

"A SPAD" scenario: *Train Driver fails to stop at signal*

Question:

"Of the two elements which one is more and how much more important with respect to the influence on distraction?"

Distraction	Extreme		Very strong		Strong		Moderate		Equal		Moderate		Strong		Very strong		Extreme		Distraction
Training	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Familiarity
Information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Communication

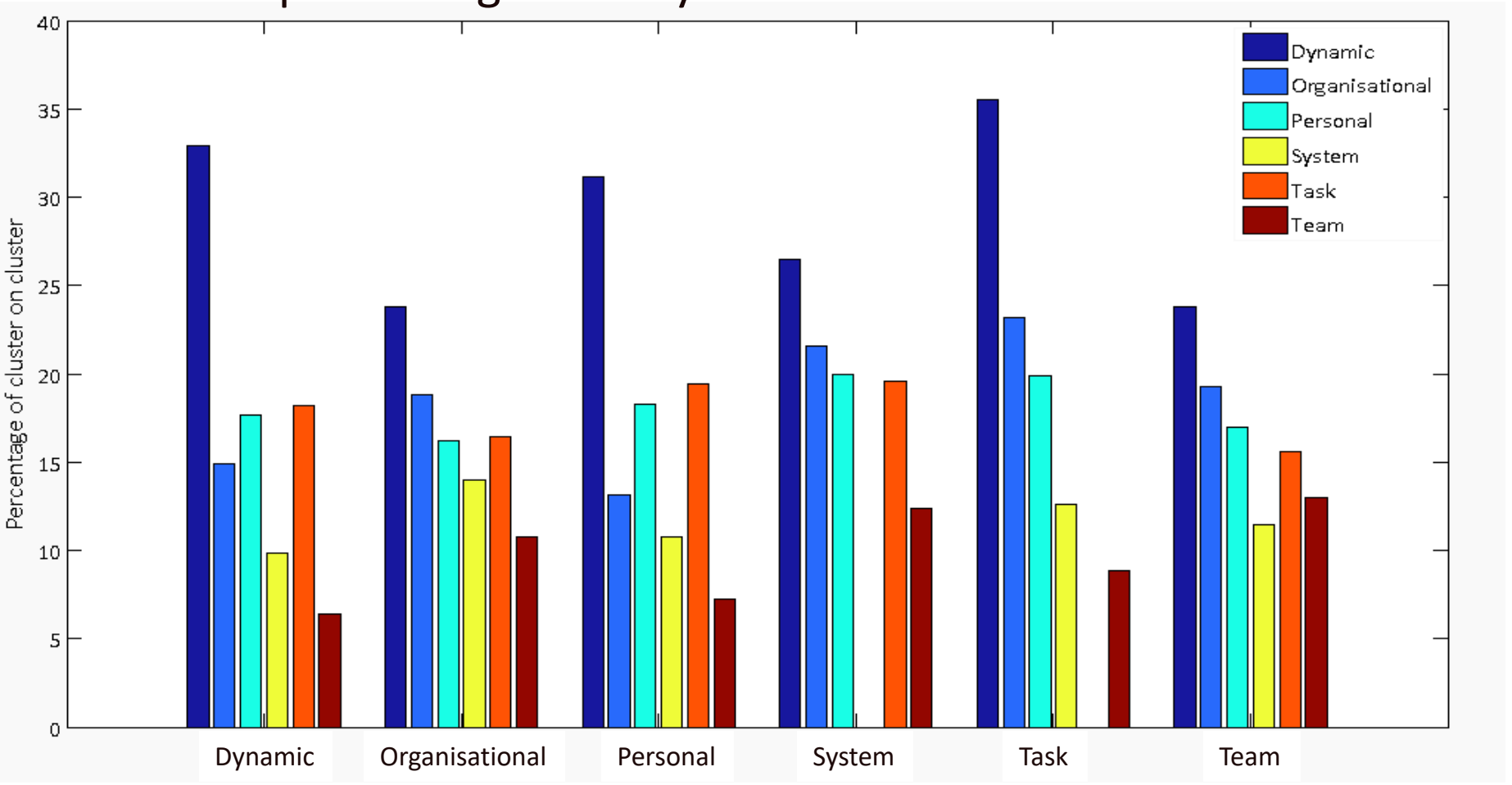
R-PSFs quantification - "A SPAD" case study

- 3 U.K. Train Operators
  - First Hull Trains: long distance
  - FirstScot Rail: short distance – commuting
  - Piccadilly Line: underground
- 54 Participants
  - 36 Train Drivers
  - 4 Driver Train Managers
  - 11 Operations Managers
  - 3 HFs experts (LUL & RSSB)

R-PSFs quantification - "A SPAD" case study

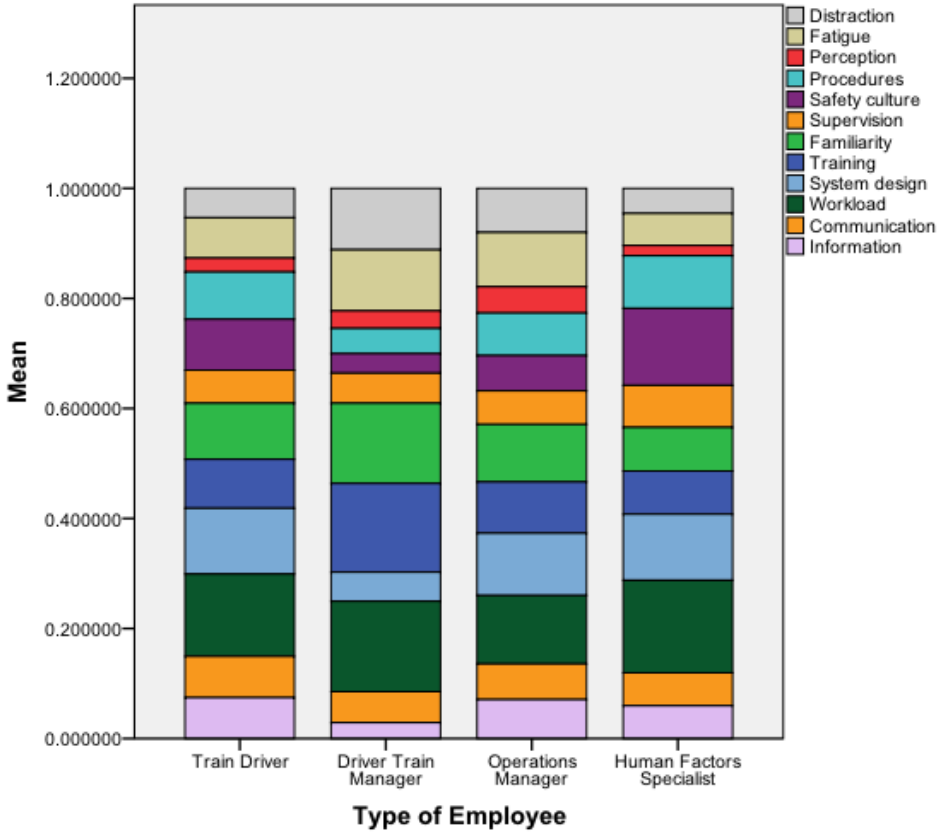
R-PSFs clusters "weighting"

- Groups **NOT** significantly different



R-PSFs quantification - "A SPAD" case study

Aggregated results per type of employee for elements



- Workload most important for all
- Safety culture for TD, HF
- Training for DTM
- Familiarity for all
- Procedures for TD, HF
- Fatigue for DTM and OM
- System design TD, OM, HF

R-PSFs quantification - "A SPAD" case study

Data not normally distributed → non parametric tests

R-PSFs weighting does not differ for:

- type of operators
- age
- SPAD experience

The only identified difference was for "*Procedures*" vs. "*Years of experience*"

R-PSFs quantification - most likely error

- A train driver may experience a SPAD because they fail to
  - detect the signal
  - interpret the signal
  - act as required

- Which one is the most likely type of error?

- It is derived from $$HuPeROI = \sum_{i=1}^{n} w_i \times r_{ij}$$

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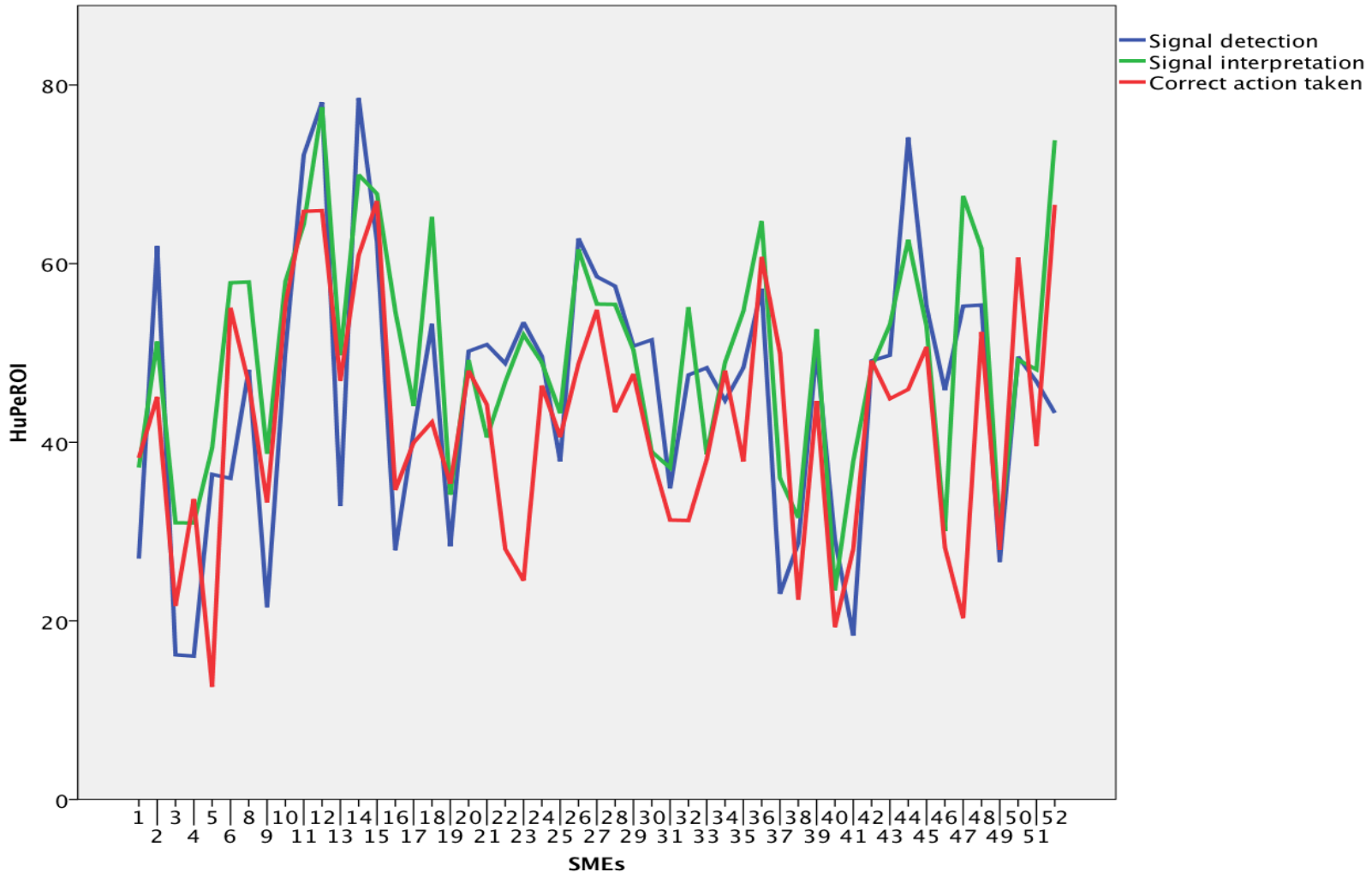
R-PSFs quantification - most likely error

Rating of Railway Performance Shaping Factors												
Scenario - Errors	**R-PSFs**											
SPAD Train driver, open line (not tunnel), day operation, good weather conditions, good visibility	**Training** (incl. experience)	**Familiarity** (incl. expectation and routine)	**Distraction** (incl. concentration, vigilance, situational awareness loss)	**Fatigue** (incl. shift pattern and fitness to work)	**Perception** (incl. interpretation)	**Workload** (incl. stress and time pressure)	**Communication** (incl. teamwork)	**Quality and Trust in Information**	**Safety culture** (incl. SMS)	**Quality of Procedures**	**Supervision**	**System design** (incl. HMI)
Job at time of SPAD Train driver **fails** to stop the train before passes signal at danger	0 = no training, 50= some training, 100= very good training	0 = no familiarity 50 = some level of familiarity 100 = high levels of familiarity	0 = very distracted 50 = some distraction 100 = no distraction	0 = too fatigued 50 = some level of fatigue 100 = no fatigued	0 = no perception 50 = some perception 100 = high perception levels	0 = extreme workload 50 = some level of workload 100 = no workload	0 = poor quality 50 = average quality 100 = very good quality	0 = poor quality 50 = average quality 100 = high level quality	0= poor safety culture 50 = some safety culture 100= very good safety culture	0 = poor quality 50 = average quality 100 = very good quality	0 = no supervision distracted 50 = some supervision 100 = very good supervision	0 = poor system design 50 = average quality 100 = very good system design
1. **Signal detection**	80	80	10	30	20	60	70	70	70	80	80	50
2. **Signal interpretation**	80	60	20	40	10	60	70	70	70	80	80	50
3. **Action executed**	70	40	10	30	20	50	60	40	70	50	50	50

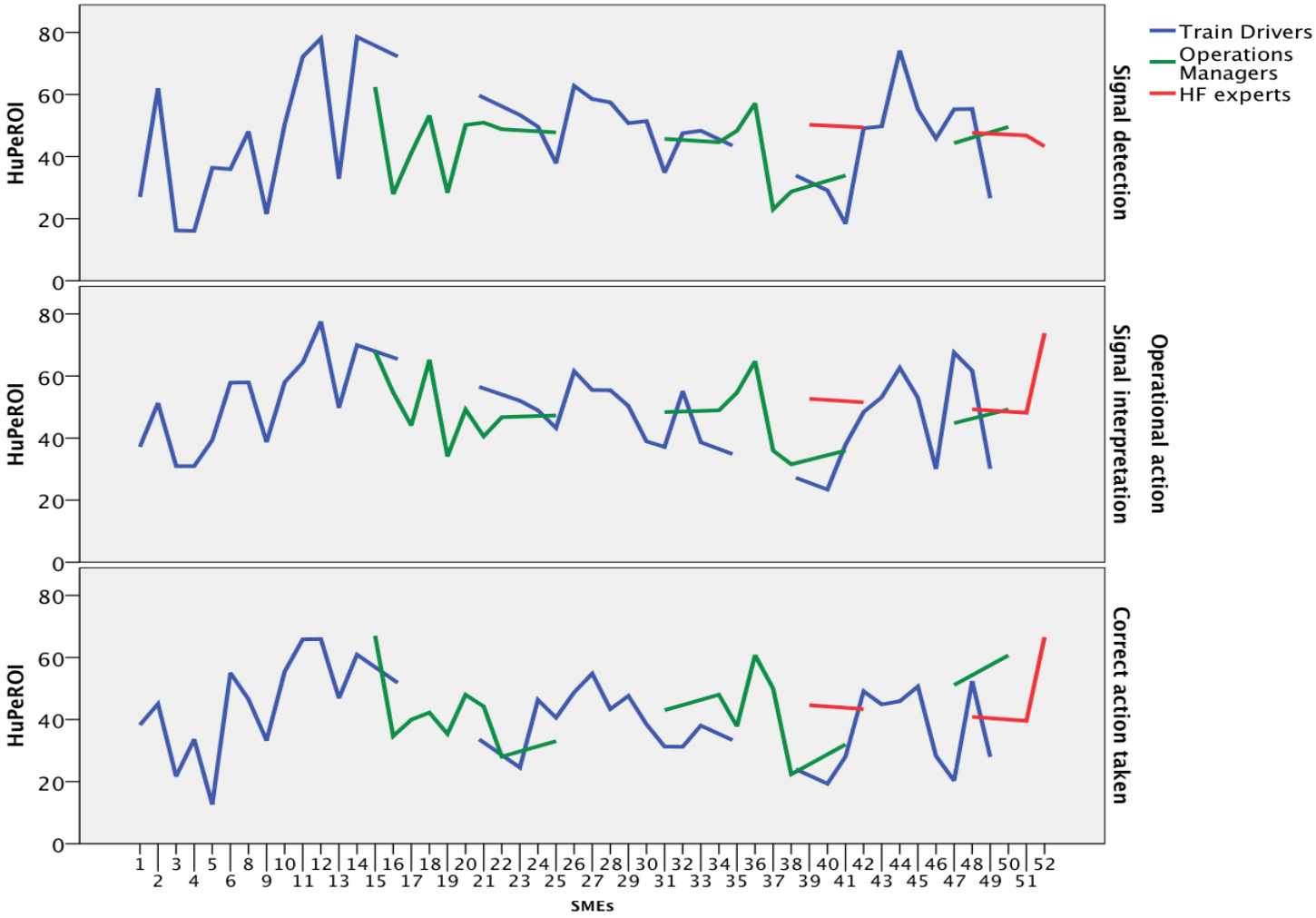
R-PSFs quantification - most likely error



R-PSFs quantification - most likely error

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
						Lower Bound	Upper Bound		
HuPeROI signal detection	Train Driver	34	46.6603	17.0003	2.9155	40.7286	52.5920	16.0508	78.5344
	Operations Manager	14	43.8982	12.2273	3.2679	36.8384	50.9580	23.0325	62.4113
	HFs expert	3	46.7718	3.4724	2.0048	38.1458	55.3978	43.2878	50.2326
	Total	**51**	**45.9086**	**15.2204**	**2.1313**	**41.6278**	**50.1894**	**16.0508**	**78.5344**
HuPeROI signal interpretation	Train Driver	34	49.0766	13.0443	2.2371	44.5252	53.6280	23.4137	77.5124
	Operations Manager	14	49.1045	11.5242	3.0800	42.4506	55.7584	31.5390	67.8134
	HFs expert	3	58.2026	13.7110	7.9161	24.1425	92.2626	48.1374	73.8187
	Total	**51**	**49.6211**	**12.6113**	**1.7659**	**46.0741**	**53.1681**	**23.4137**	**77.5124**
HuPeROI action executed	Train Driver	34	40.9721	13.4339	2.3039	36.2848	45.6594	12.6227	65.9363
	Operations Manager	14	44.2281	12.6978	3.3936	36.8967	51.5596	22.3827	67.0106
	HFs expert	3	50.2642	14.3512	8.2857	14.6139	85.9145	39.5895	66.5786
	Total	**51**	**42.4125**	**13.2401**	**1.8540**	**38.6887**	**46.1364**	**12.6227**	**67.0106**

R-PSFs quantification - most likely error



R-PSFs - limitations - areas to explore

- Design of questionnaire
  - time consuming
  - user (un)friendly
- How R-PSFs quantification may change having other sample, e.g. other line or personnel

Conclusion

Conclusion

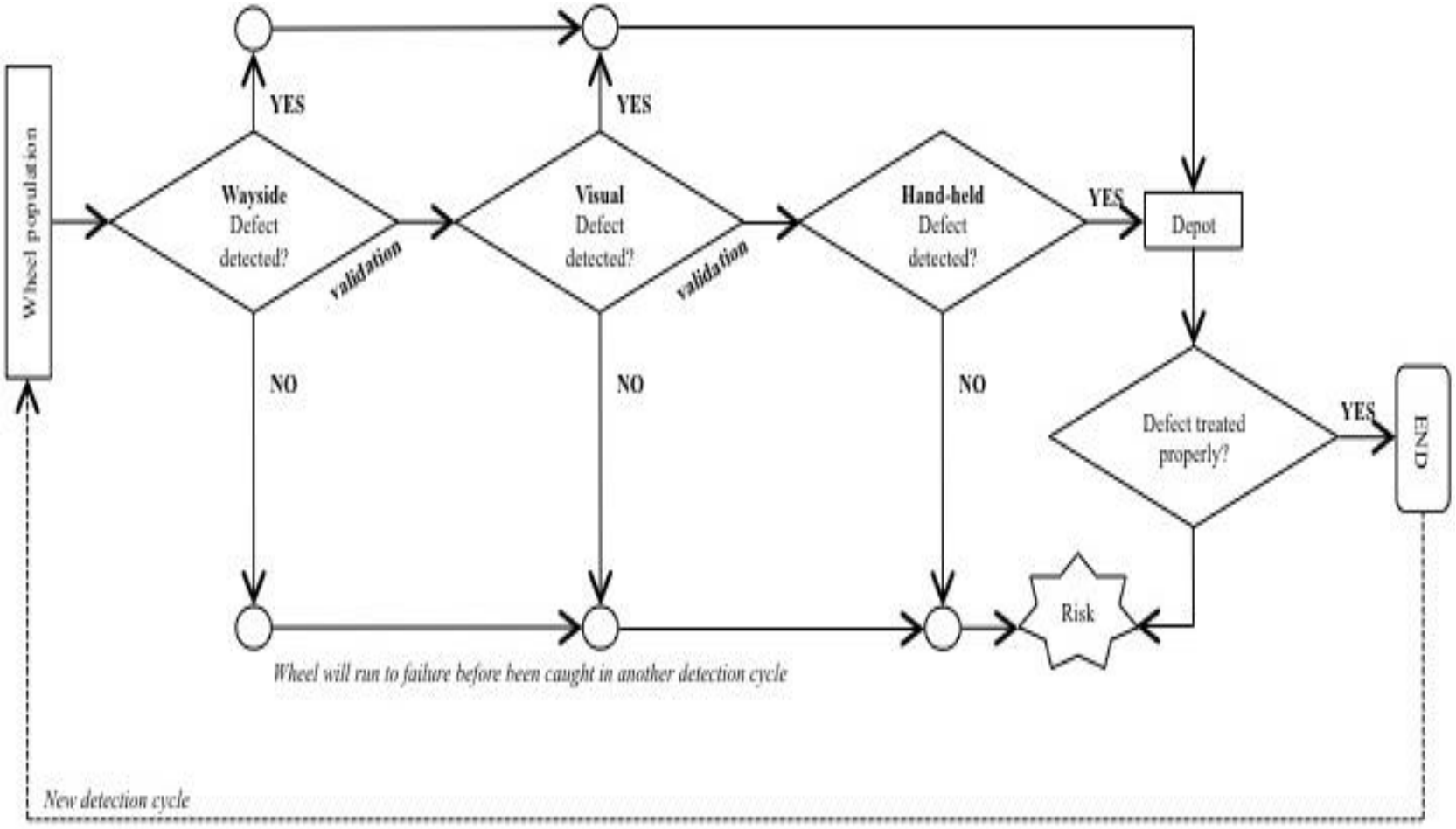
HuPeROI aims to:

- assess human performance
- suggest mitigation strategies and areas to be improved
  - no mobile phones in the train cabin
- design the system to prevent potential human failures
  - equipment in train cabin
- identify differences between personnel perspectives

Future work

- Implementation of HuPeROI for several railway operational scenarios in collaboration with the industry
- Incorporate the HuPeROI into the Safety Management Systems of organisations
- Transfer the HuPeROI concept to other transport modes and other industries
- Accelerate technology uptake
- Convert the HuPeROI into a software package to be used by relevant stakeholders

Wheel defect detection process



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The human performance railway operational index—a novel approach to assess human performance for railway operations

Miltos Kyriakidis, Arnab Majumdar and Washington Y. Ochieng

https://doi.org/10.1016/j.ress.2017.10.012

Thank you…

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