Measuring Safety Through the **Distance Between System States** with the RiskSOAP Indicator

Dr Maria **Mikela** CHATZIMICHAILIDOU[a],

Dr Nektarios KARANIKAS[b], Dr Ioannis DOKAS[c]

[a]Imperial College London, United Kingdom

[b]Amsterdam University of Applied Sciences, The Netherlands

[c]Democritus University of Thrace, Greece

Imperial College London

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Outline

1. Context
2. Problem statement
3. Solution
4. Methodology
5. Applications
6. Results
7. Conclusions

Context

- Modern engineering systems = complex socio-technical structures
  - mission to offer services of high quality, ensure owners' profitability
  - safety & security
  - consist of many parts, controlled by human or automated agents spread throughout different hierarchical levels & networks
  - **accidents are inevitable**; acknowledged need for the use of **systems-theoretic tools to support safety-driven design & operation**
  - **agents be enabled** to perceive & comprehend threats/vulnerabilities & project what they may entail → ***risk-focused Situation Awareness (risk SA)***

Problem statement

- Risk SA presupposes that an agent is offered an **indication of the variability of the system states** to update his/her mental model & adjust the system processes accordingly

- Most critical high-level risk: large **gap between work-as-imagined & work-as-done**

- To maintain the safety levels that the system was originally planned for, controllers must be **aware of the distance between system design & operation**, i.e. maintain a high **risk SA**

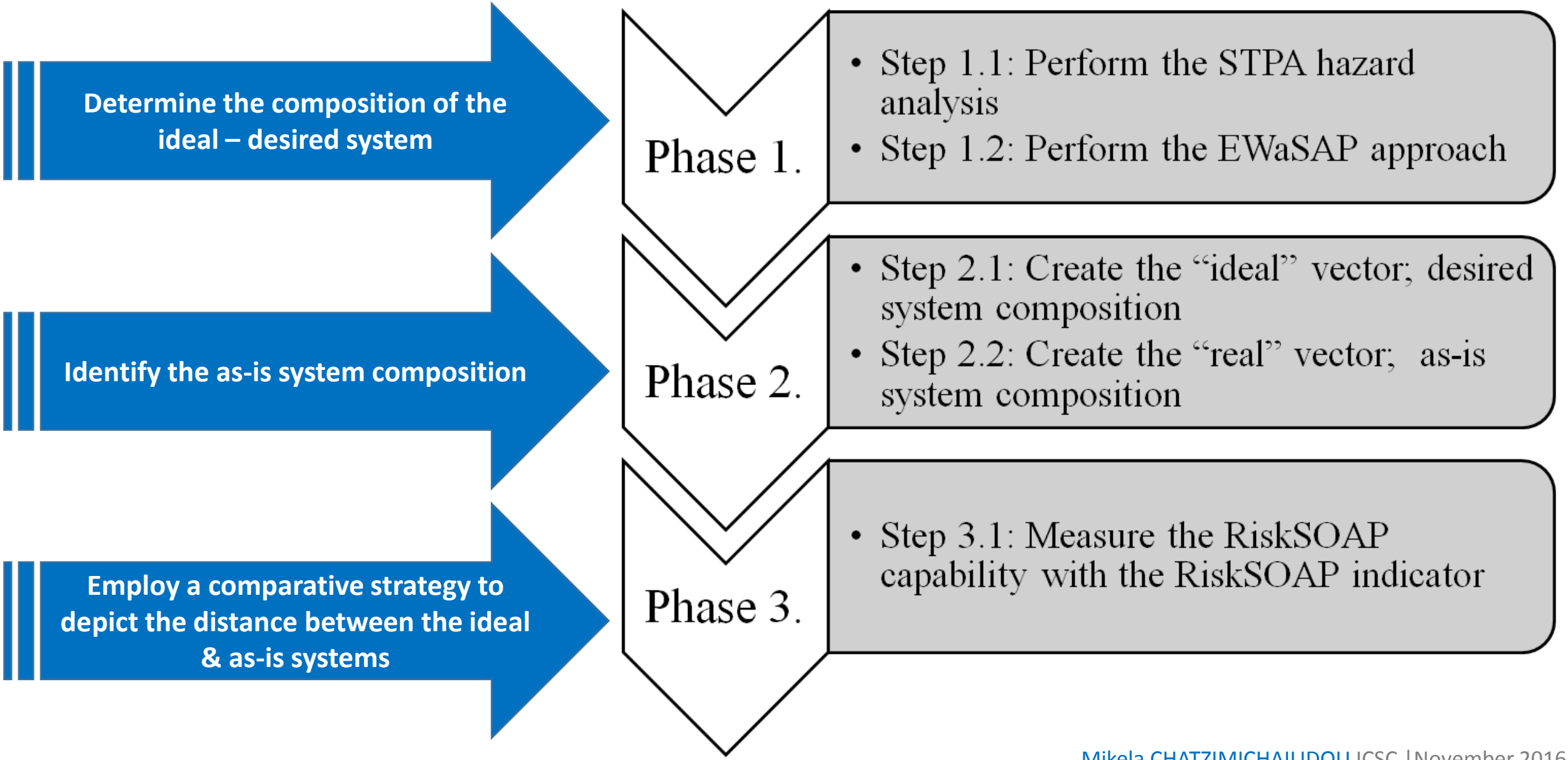
Solution

- Agent's risk SA supported by the **system components & composition**
  - ***system's risk SA provision (RiskSOAP) capability***: operationalised through a **quantification of the differences of various system versions** in regard to safety

- RiskSOAP may be increased or decreased by including or excluding, upgrading, downgrading or maintaining **system parts & elements**, or their properties, throughout the system's lifecycle

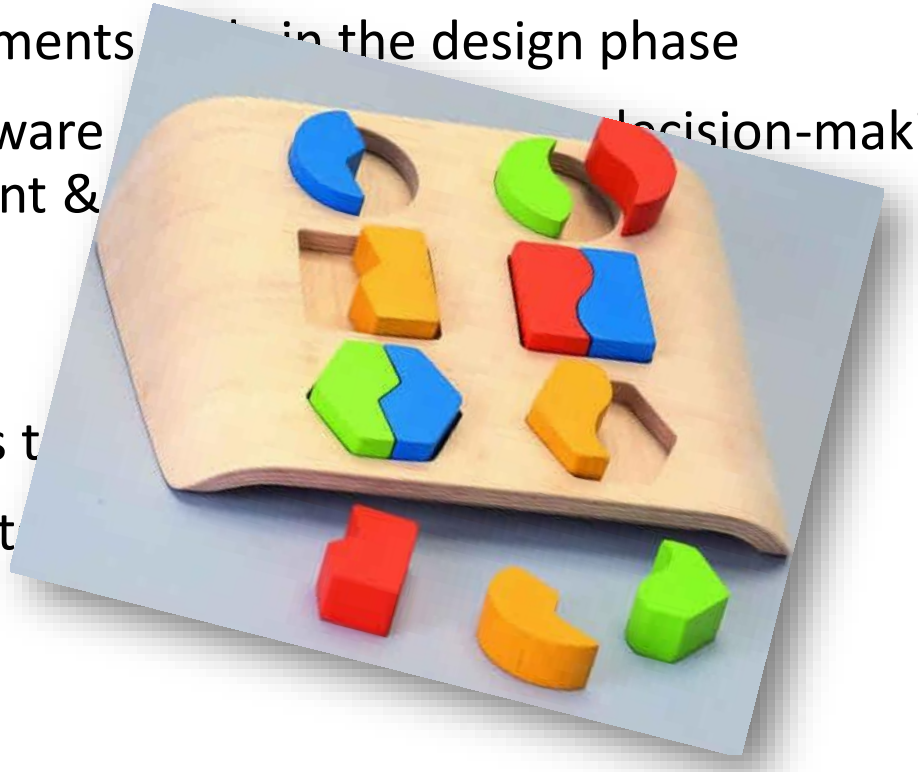
- **RiskSOAP methodology**
  - summary of previous publications as a means to provide an overall view & a comprehensive demonstration of its applicability

RiskSOAP methodology



Methods & tools

- **STPA** (Leveson, 2011)
  - Safety = a dynamic control problem & an emergent property
  - Accidents ≠ chains of event & component failures
  - Non-probabilistic top-down approach; safety requirements in the design phase
  - Inadequate control actions & causal factors (e.g. software decision-making flaws, conflicts between controllers, poor management &



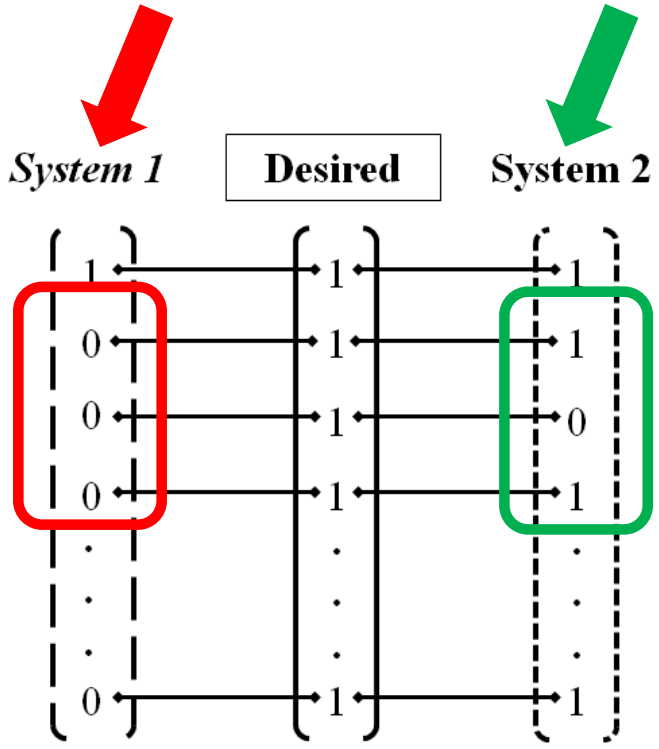
- **EWaSAP** (Dokas et al., 2013)
  - Structured method for identifying early warning signs t
  - Awareness actions: provide warning messages & alert

- **Dissimilarity measure** (pattern matching)
  - Rogers-Tanimoto:

$$RTd(i,r) = \frac{2S10 + 2S01}{S11 + S00 + 2S10 + 2S01}$$

Hypothesis checked

"Provided that there are **more than one versions** of the same system that differ in their composition, the RiskSOAP methodology is adopted and the **RiskSOAP** indicator is calculated **as many times as the different alternative versions** of the system. After obtaining these values, it is expected that the **lowest value** for the RiskSOAP indicator will be returned **for the system version that is proclaimed as less vulnerable**, and vice versa."



RiskSOAP indicator for *System 1*

RiskSOAP indicator for **System 2**

IF

RiskSOAP indicator for **System 2**

<

RiskSOAP indicator for *System 1*

THEN

System 2 closer to the desired system version than *System 1*

3 Case studies

- **ACROBOTER**
  - robotic installation for manipulating small objects autonomously/in cooperation with humans
  - original system failed to meet its purposes & deliver the tasks as described in the project scope

- **Überlingen mid-air collision accident**
  - Johnson, 2004; BFU, 2002: technical (e.g. optical STCA, phone connection, TCAS downlink) & organisational (e.g. detailed/unified directives, aid to the ATC) deficiencies

- **Road Tunnel in Greece**
  - planned renovation
  - tunnel not yet monitored by exclusive tunnel control centre

Results I - ACROBOTER

System Elements	STPA & EWaSAP	Operated system	Designed system
Present	213	96	92
Absent	0	117	121
Vectors' length	213	213	213
RiskSOAP indicator		=2*117 + 2*0 / 96 + 0 + 2*117 +2*0 =0.7091	=2*121 + 2*0 / 92 + 0 + 2*121 +2*0 =0.7246
Difference between the 'as-is' system versions		=0.7246 - 0.7091 =0.0155	

Results II - Überlingen mid-air collision

System Elements	STPA & EWaSAP	Operated system	BFU (2002) & Johnson (2004)
Present	279	74	134
Absent	0	205	145
Vectors' length	279	279	279
RiskSOAP indicator		=0.8471	=0.6840
Difference		=0.1631	

Results III – Road tunnel

System Elements	STPA & EWaSAP	Operated system	Directive 2004/54/EC & PIARC
Present:	191	109	153
Absent:	0	82	38
Vector's length:	191	191	191
RiskSOAP indicator		=0.6007	=0.3319
Difference		=0.2688	

Observations

- RiskSOAP **numerical** expression; differences between system versions communicated in a **simple & understandable** manner → **lower RiskSOAP indicator**:
  - **safer system**; system components & characteristics effectively operationalised
  - safety **risk SA** of the system agent(s) **enhanced**

- Calculation before & after changes; **management can act upon system changes** based on: the different values, their fluctuation & the priorities/constraints of the industry

- 3 apps; **improved system compositions** correspond to **lower indicator** values

- Potential for **safety improvements** even for **systems** contemplated as **safe enough**

Final remarks I

- RiskSOAP measurement: **distance** of systems **from** their **ideal** composition & potential for further **improvements** in terms of safety constraints generated through STPA & EWaSAP

- RiskSOAP indicator
  - **selection criterion** between **alternative design versions** of the same system; by comparing the vectors corresponding to different design versions
  - **decision-making tool** when evaluating **system changes** with reference to the ideal system; system composition **modifications** to shorten the distance between vectors & 'lessen' the operated-ideal system dissimilarity
    - **criterion for evaluating modifications** that might affect the minimum acceptable safety level of the system under consideration; **threshold value** can be set

Final remarks II

- STPA & EWaSAP require **experienced & well qualified** analysts, supported by interdisciplinary team with common & complementary understanding of the system under study

- **Subjective** interpretation of the value of the indicator; may differ across systems & designers, affecting the degree of interventions in the systems

- **Binary**-based indicator; no intermediate case between absence-presence, but variables may have true value ranging between ‘0’ & ‘1’

Future work

- Consider dissimilarity measures which account for **intermediate** states of system components

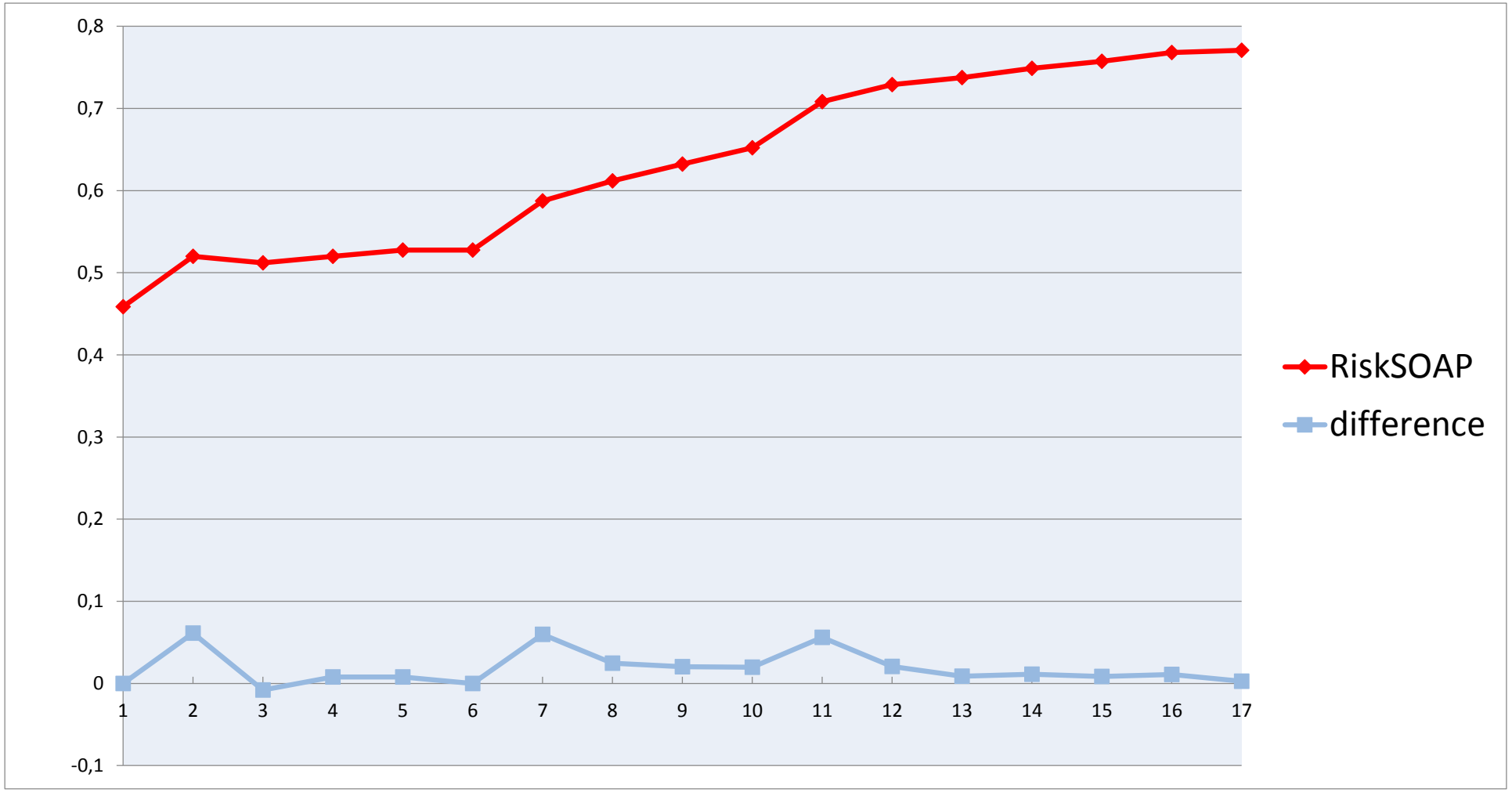
- STPA analysis applicable to:
  - emergent properties (other than safety) such as **security & quality**
  - various business functions such as production & **finance**

    → if purpose of system related to economics, then system elements decided by economic/**econometric** models

- RiskSOAP as a **leading safety indicator**; awareness of system deviations from its desired state → (re)design & operation of safer systems

Leading Safety Indicator.. *maybe? how?*

Überlingen RiskSOAP values along the accident's timeline [preliminary results]



Thank you!

contact:

m.chatzimichailidou@imperial.ac.uk

mikelachatzimichailidou@gmail.com

http://www.imperial.ac.uk/people/m.chatzimichailidou

ResearchGate, LinkedIn, Twitter, fb

Imperial College London

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