Imperial College London & Lloyd's Register Foundation

Design & Plan for Maintenance: A STAMP-based Dissimilarity Indicator for Railways

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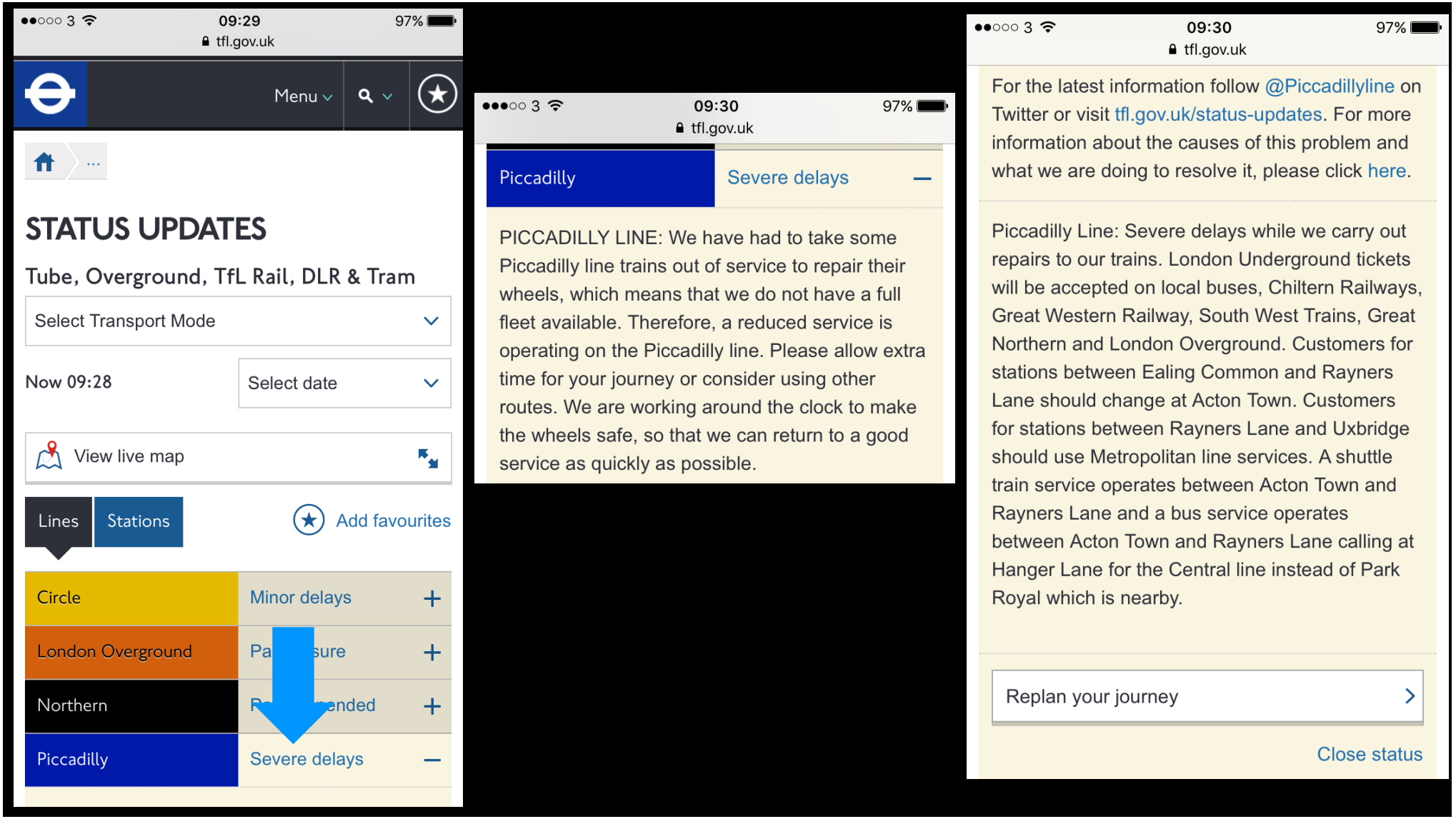
The Project

- Partners
  - Imperial College London, UK
  - University of Twente, NL
  - Lulea Technical University, SE
- Duration: October 2016 - June 2018
- 1st project meeting: March 2017

Importance of Maintenance

- Inadequate maintenance → disastrous consequences for life & property (Zerbst et al, 2005)
- Lifecycle costs of rolling stock: highest costs for maintenance ≈ 1.5 times > new building car (Van Dongen, 2016)
  - Why so high? Withdrawal of coaches causes high cost, complaints & displeasure [Ex. London Underground, 3rd Dec 2016]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Piccadilly
Severe delays
PICCADILLY LINE: We have had to take some Piccadilly line trains out of service to repair their wheels, which means that we do not have a full fleet available. Therefore, a reduced service is operating on the Piccadilly line. Please allow extra time for your journey or consider using other routes. We are working around the clock to make the wheels safe, so that we can return to a good service as quickly as possible.
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For the latest information follow @Piccadillyline on Twitter or visit tfl.gov.uk/status-updates. For more information about the causes of this problem and what we are doing to resolve it, please click here.
Piccadilly Line: Severe delays while we carry out repairs to our trains. London Underground tickets will be accepted on local buses, Chiltern Railways, Great Western Railway, South West Trains, Great Northern and London Overground. Customers for stations between Ealing Common and Rayners Lane should change at Acton Town. Customers for stations between Rayners Lane and Uxbridge should use Metropolitan line services. A shuttle train service operates between Acton Town and Rayners Lane and a bus service operates between Acton Town and Rayners Lane calling at Hanger Lane for the Central line instead of Park Royal which is nearby.
Replan your journey
Close status

Maintenance as-is

- (a) Fragmented (e.g. rolling stock, depots & tools; wide-spread); (b) highly (if not entirely) dependent on human experts
- (a) No design focus on maintainability; (b) no critical & frequent quality checks on product
- End-user does not participate in the design & production process
- Retrospective measures: no desired project results → make changes
- Underestimated impact of maintainer & operator in design & production process

➢ Late maintenance → high costs; long lead times of repairs; safety

Railway Objectives

- Design & plan for maintenance
- Dynamic maintenance planning; constant attention VS initial investment
- Use warning indicators; diagnose symptoms & failures; real-time monitoring (i.e. GOTCHA system)
- Maintenance management shall understand various "error" producing conditions & serve as an input to modify policies & develop better guidelines for railway maintenance tasks

"The core value of maintenance decision making is the determination of the values of all options the decision maker has to make good trade-offs between the available options" (Tiddens et al, 2015)

"Advanced maintenance techniques are practices that can support maintenance decision making by taking the current and future state of assets into account" (Tiddens et al, 2015)

"Uncertainties in the technique and uncertainties in the input data lead to uncertainties in the prediction" (Bo et al., 2010)

"results from the technique, namely detection, diagnosis and prognosis can be used to optimise maintenance decisions" (Tiddens et al, 2015)

"predictions are especially useful when the system deterioration varies between the various operational situations the asset is exposed to" (Tiddens et al, 2015)

"Degradation-based predictions offer the opportunity to assess the current state of the equipment and, based on the trending of the prognostic parameter, make estimations of the remaining life" (Tiddens et al, 2015)

"the quality of the prediction has to be very-high." (Tiddens et al, 2015)

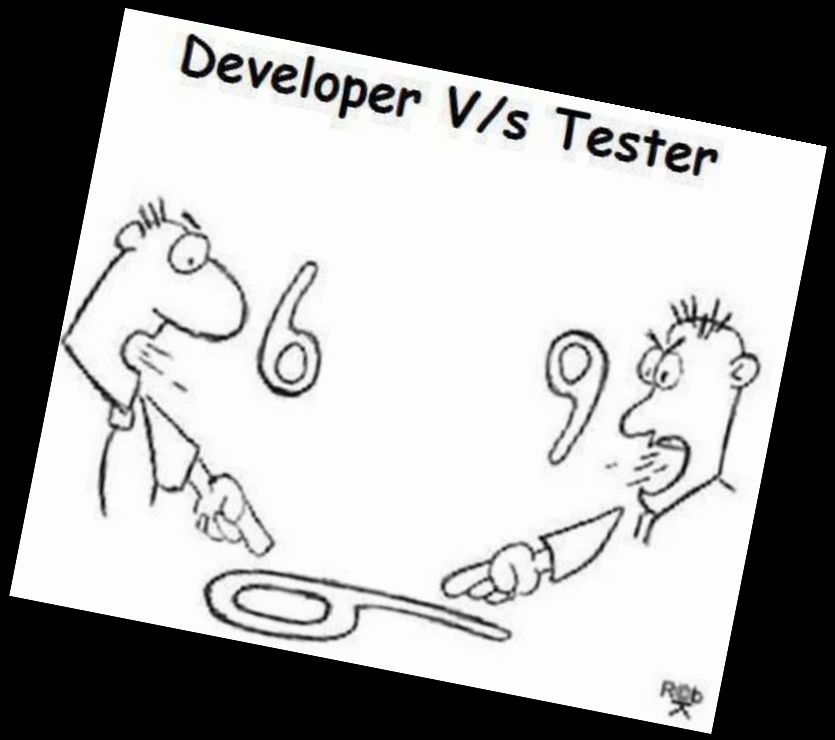
Problem Statement

x Difference between
the system as-imagined &

{ : Design & Maintenance

the system as-done

x Addressing maintenance retrospectively



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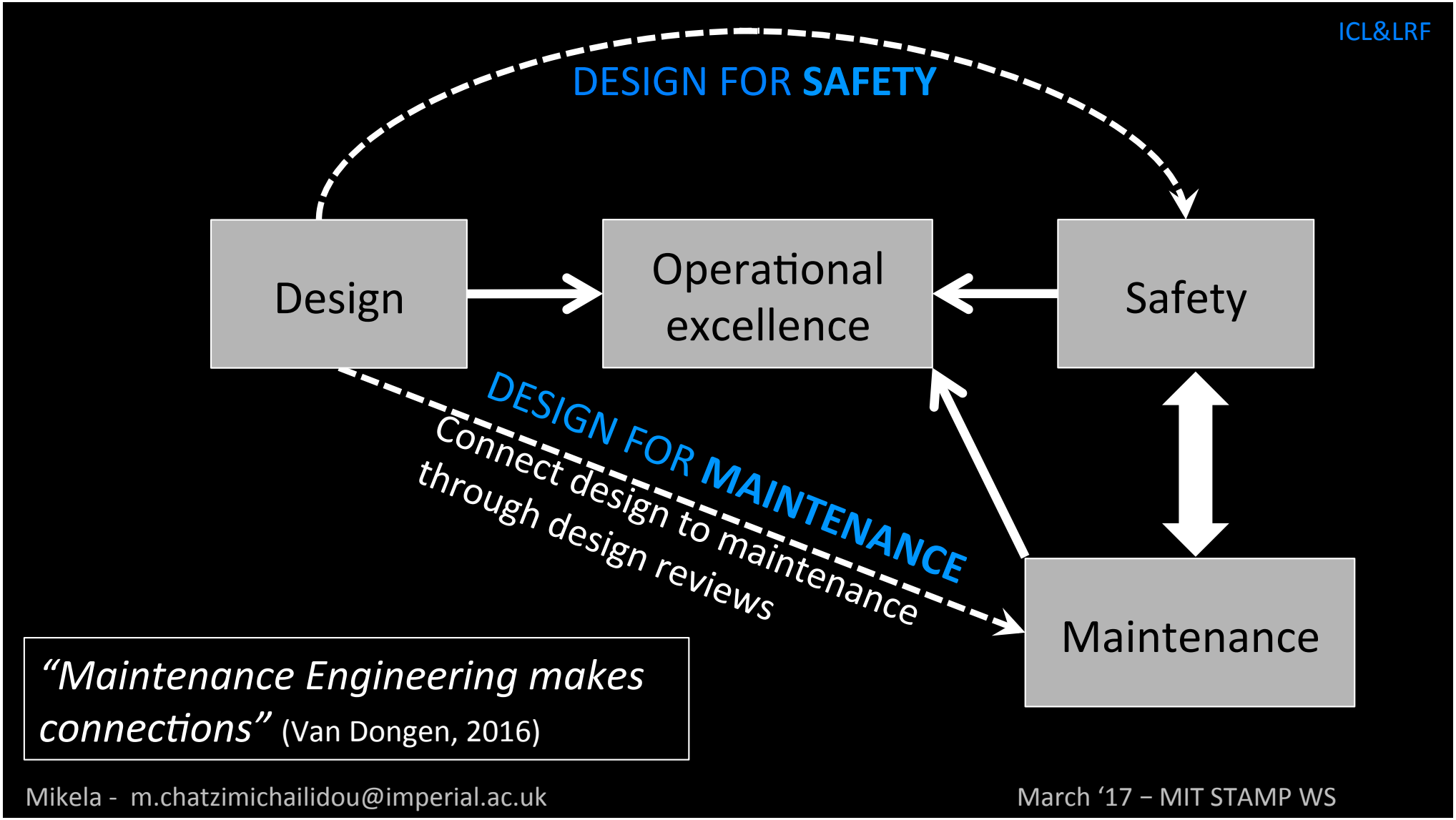
ICL&LRF
DESIGN FOR SAFETY
Design
Operational excellence
Safety
DESIGN FOR MAINTENANCE
Connect design to maintenance through design reviews
Maintenance
"Maintenance Engineering makes connections" (Van Dongen, 2016)
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March '17 – MIT STAMP WS

The Need

An indication of the deviations, variability & the differences between the system states/ versions

aiming to update operators' (mental) models, adjust the system processes & composition

by 'dragging' maintenance & system modifications closer to the design phase

→ **proactive maintenance-oriented methodology**

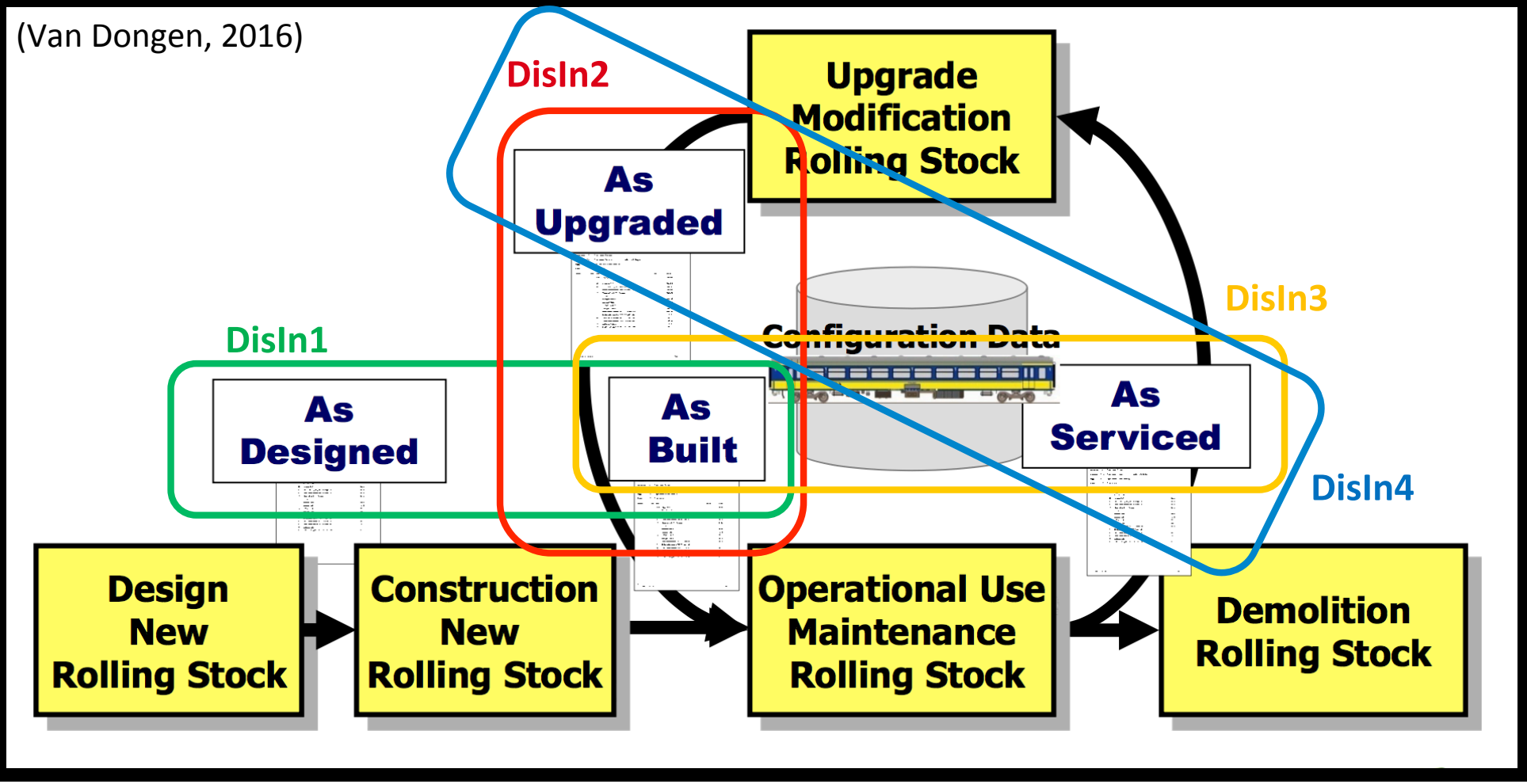
Maintenance as a Driver

- Maintenance-driven (re)design with STAMP
- Quantify the system states for the entire system's life-cycle
  - Define the desired system state to compare with the actual
  - STPA & tools, e.g. if unacceptable event → CAST

Indication of Dissimilarity

ICL&LRF

(Van Dongen, 2016)



Ideally

*Designers & Engineers

*Maintenance *(STPA, CAST)*

*Human factors *(EWaSAP,* Dokas et al, 2013*)*

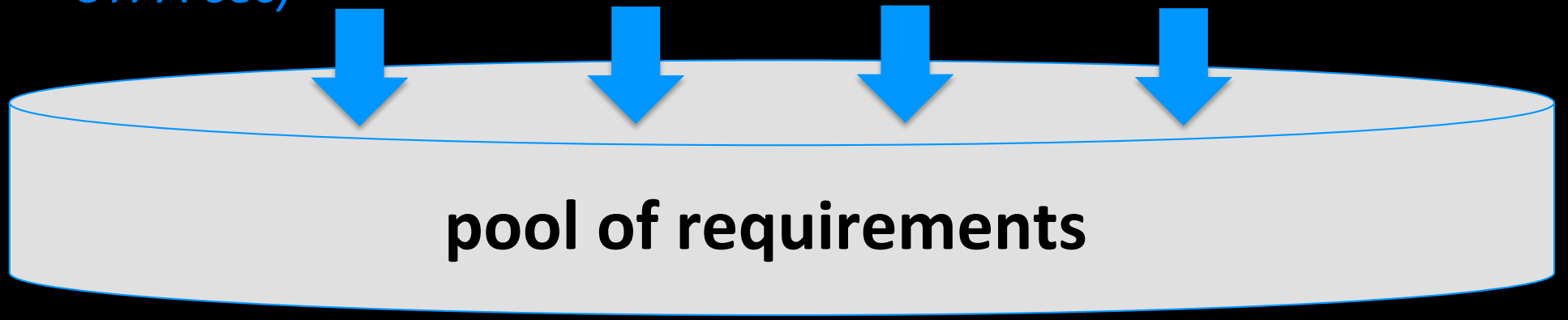
*Business analysts & Lawers

*Safety & Security *(STPA, STPA-sec)*

*Passengers

*Operators

*Suppliers & Tech availability



Next Steps

1. Define the statuses to be compared
   - The desired system
     - STPA & tools list safety, security, maintenance, human factors requirements
     - List other requirements (e.g. stakeholders, designers & engineers, analysts & lawyers) → bring asap all interested parties to the table
   - The system as-is: match it to the desired one
2. Calculate the DisInd(s)
3. Interpret the values
4. Develop a strategy to respond to distant system statuses

About this Work

- Preparatory & exploratory; not another application, but a suggestion of a STAMP-based strategy & indicator for railway maintenance
- DisIn follows the RiskSOAP* logic; validation of the rationale made
- DisIn between different system statuses as a measurement of the deviation of the one status (e.g. as-designed) from the other (e.g. as-built)
- DisIn successive values as an indication of the system's performance, i.e. enhancement or degradation of system properties throughout its life

*Introducing RiskSOAP to communicate the distributed situation awareness of a system about safety issues: an application to a robotic system (Chatzimichailidou and Dokas, Ergonomics, 2015)

Added Value for Industries

Make the Management happy! Distance of system versions from their benchmark in a single number; improvement & maintenance strategy

- DisIn as a:
  - selection criterion between alternative versions of the same system
  - decision-making tool when evaluating system changes with reference to the benchmark system
  - tool to plan system composition modifications to shorten the distance between compared system states/ versions
  - criterion for evaluating modifications that might affect the minimum acceptable performance level of the system under consideration

Thank you
questions & suggestions

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