Natural Events and Hydrogen Subsea Pipelines: Implications on Planning Inspections Based on Risk

HySchool Webinar

20/02/2024

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Presentation based on the final output of the NTNU PhD course PK8226 "**Modeling, prevention and mitigation of natural hazard-triggered technological (Natech) accidents**" administered by Dimitrios Tzioutzios and Prof. Nicola Paltrinieri

NTNU ENERGY Team Hydrogen

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Structure of the Presentation

Introduction: Scope of the Work

Methodology: Overlap Analysis

Steel-Hydrogen Interactions in H_2 Subsea Pipelines

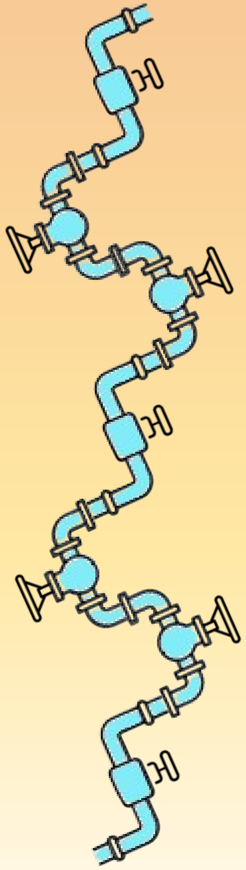
Risk-Based Inspection Methodology

Subsea Landslides and Models for Failure Probability

Proposed Approach and Expected Results

Limitations and Conclusion

Introduction: Scope of the Work

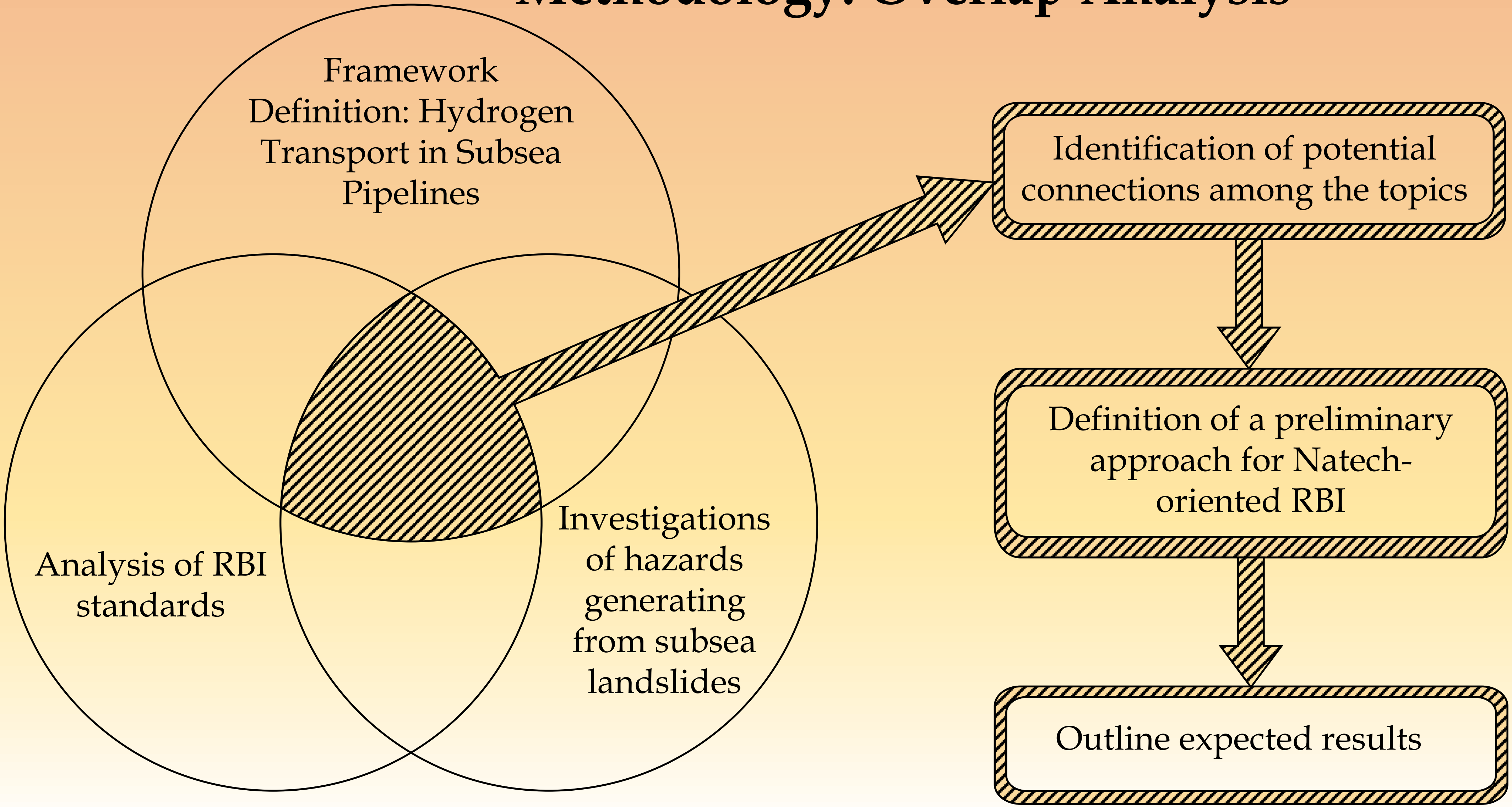


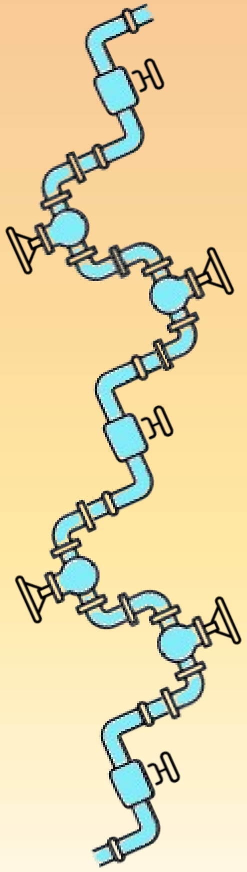
Investigate potential connections between risk-based inspection (RBI) and Natech-risk assessment in the framework of H_2 subsea pipelines

Assess weather risk-based inspection (American Petroleum Institute, 2016) could positively support Natech-risk management for hydrogen subsea pipelines

Propose a preliminary yet novel approach for Natech-oriented inspection planning

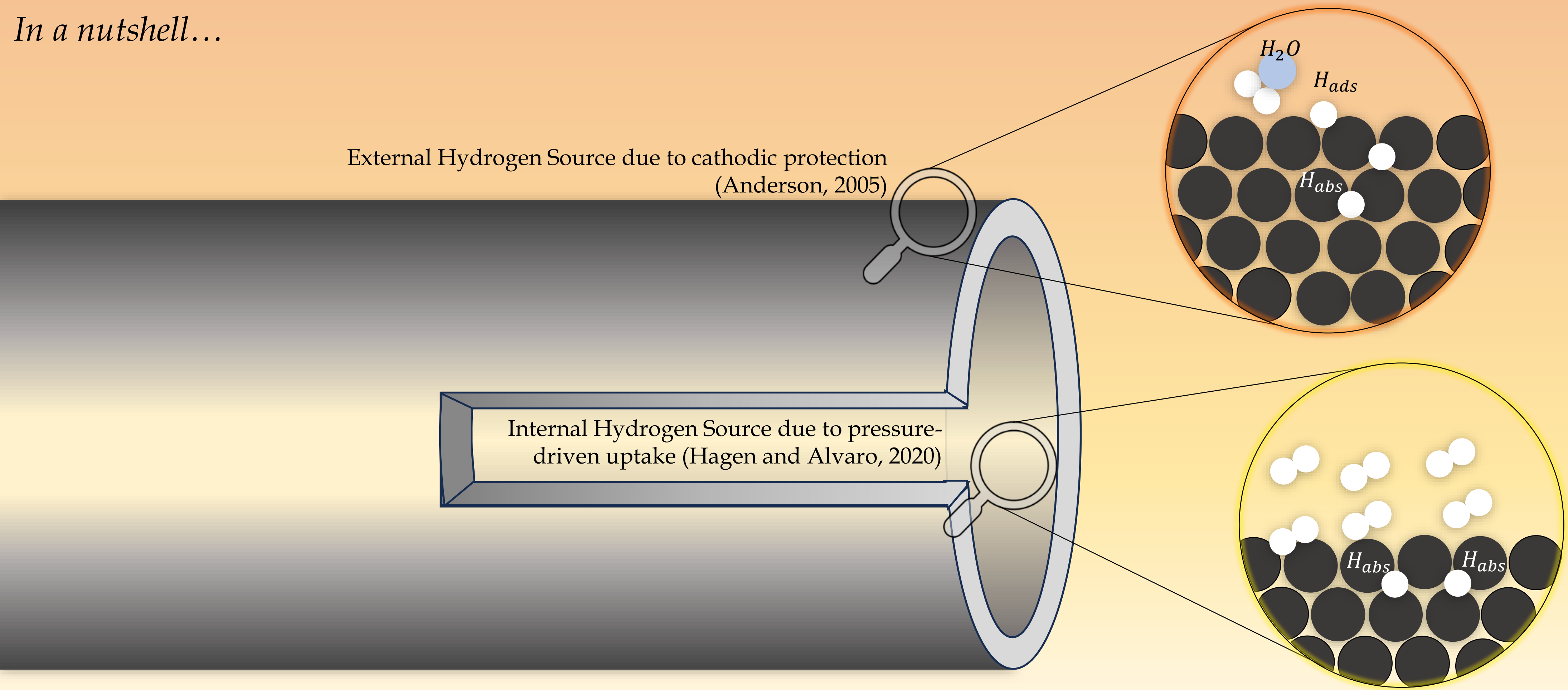
Methodology: Overlap Analysis





Steel-Hydrogen Interactions in H_2 Subsea Pipelines

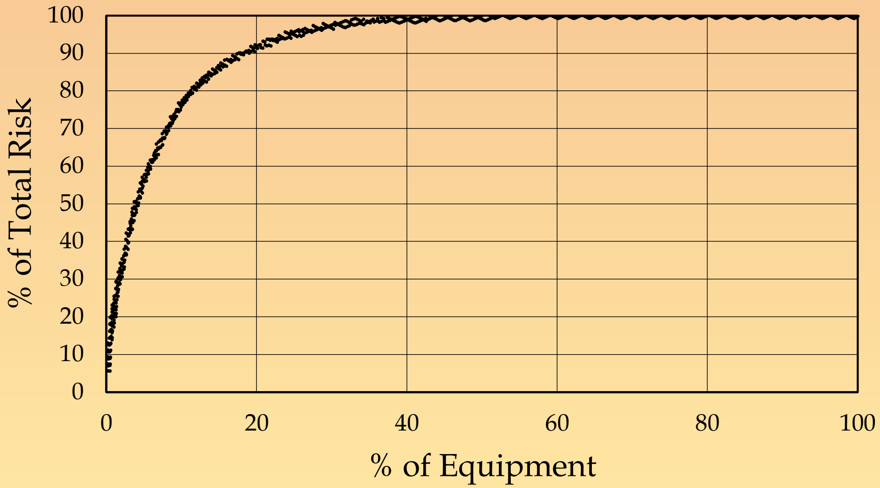
In a nutshell…



Risk-Based Inspection Methodology

In a nutshell…

$$R_i(t) = PoF(t)_i \cdot CoF_i$$



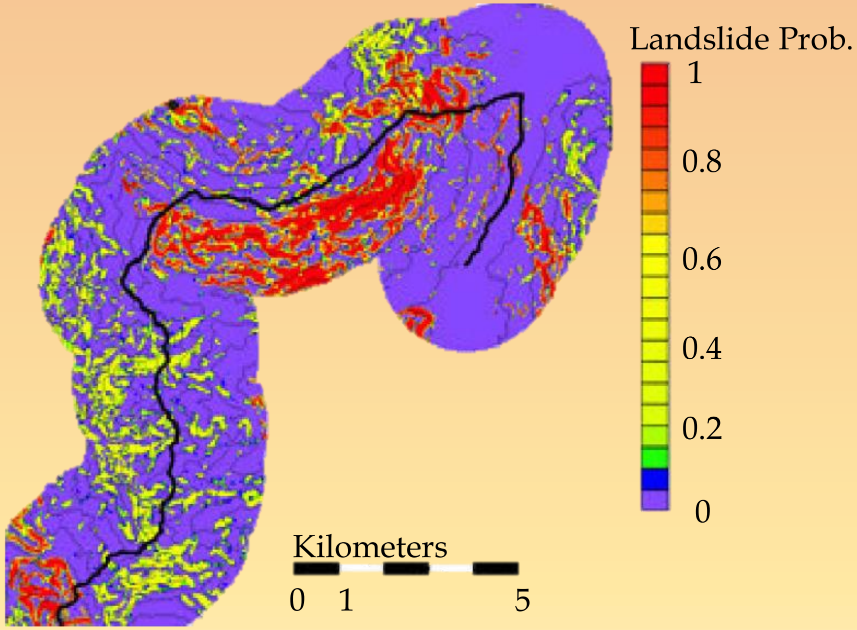
PoF depends on the active damage mechanisms! (American Petroleum Institute, 2019)

For a hydrogen pipeline, *PoF* should be established based on the active hydrogen damages, fostered by the two hydrogen sources!

But what about hazards deriving from Natech sources?

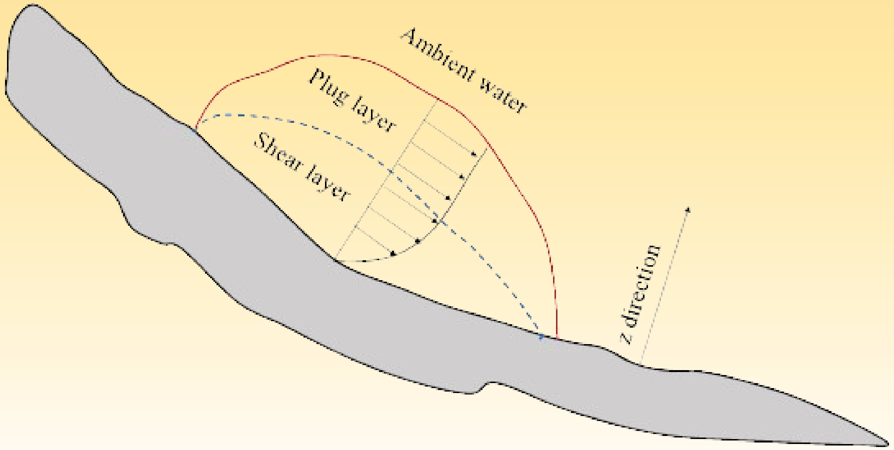
Subsea Landslides and Models for Failure Probability

Several studies on pipeline failure probability due to landslides exist in literature.



(Alvarado Franco et al., 2017): topography-oriented model for onshore pipelines considering ground characteristics and rainfall conditions to assess **failure probability**.

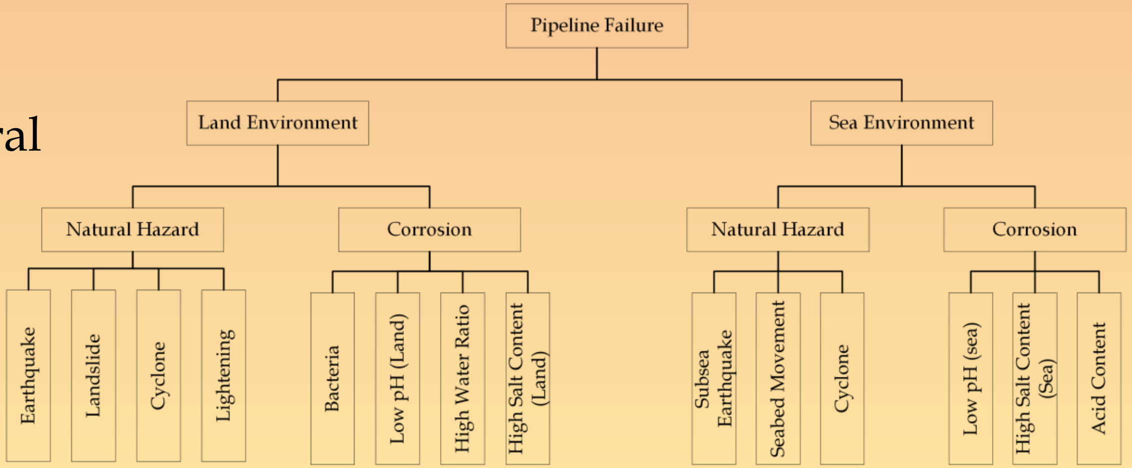
(Qian and Das, 2019): a finite element model to investigate subsea pipeline movement (connected to **failure probability**) when impacted by a destructive debris flow.

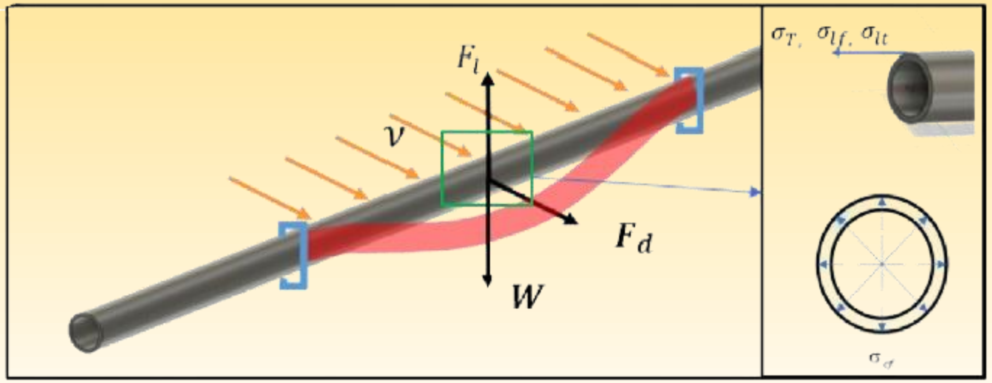


Subsea Landslides and Models for Failure Probability

Several studies on pipeline failure probability due to landslides exist in literature.

(Badida et al, 2019): a fuzzy fault-tree analysis to evaluate pipeline **failure probability** due to natural hazards (including landslides) coupled with corrosion processes.





(Song et al., 2023): a model to calculate **failure probability** (based on angle and location of impact) of a pipeline exposed to a debris flow considering operative conditions.

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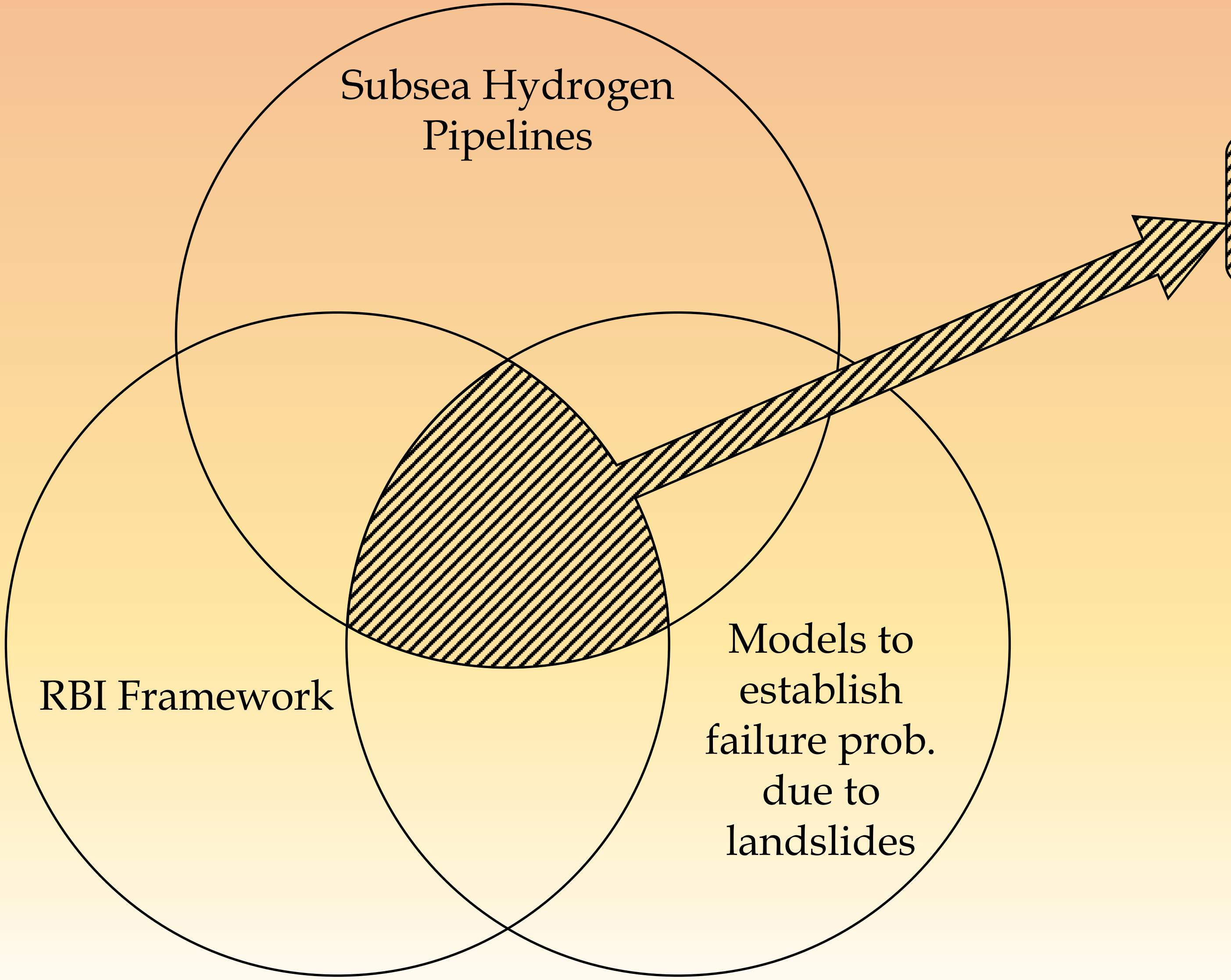
Preliminary Novel Framework and Expected Results

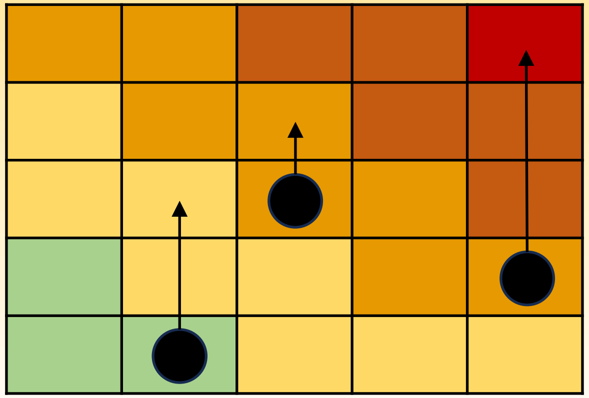


Modified RBI Risk Calculation

$$R_i(t) = (PoF_{HD}(t)_i + PoF_{NH}(t)_i) \cdot CoF_i$$

$\boldsymbol{PoF_{HD}(t)_i}$ evaluates failure probability due to hydrogen damages

$\boldsymbol{PoF_{NH}(t)_i}$ evaluates failure probability due to natural hazards (subsea landslides)



$\boldsymbol{PoF_{NH}(t)_i}$ may act as a *boost* to the risk level, indicating components and/or pipe sections that require intensive inspection activity

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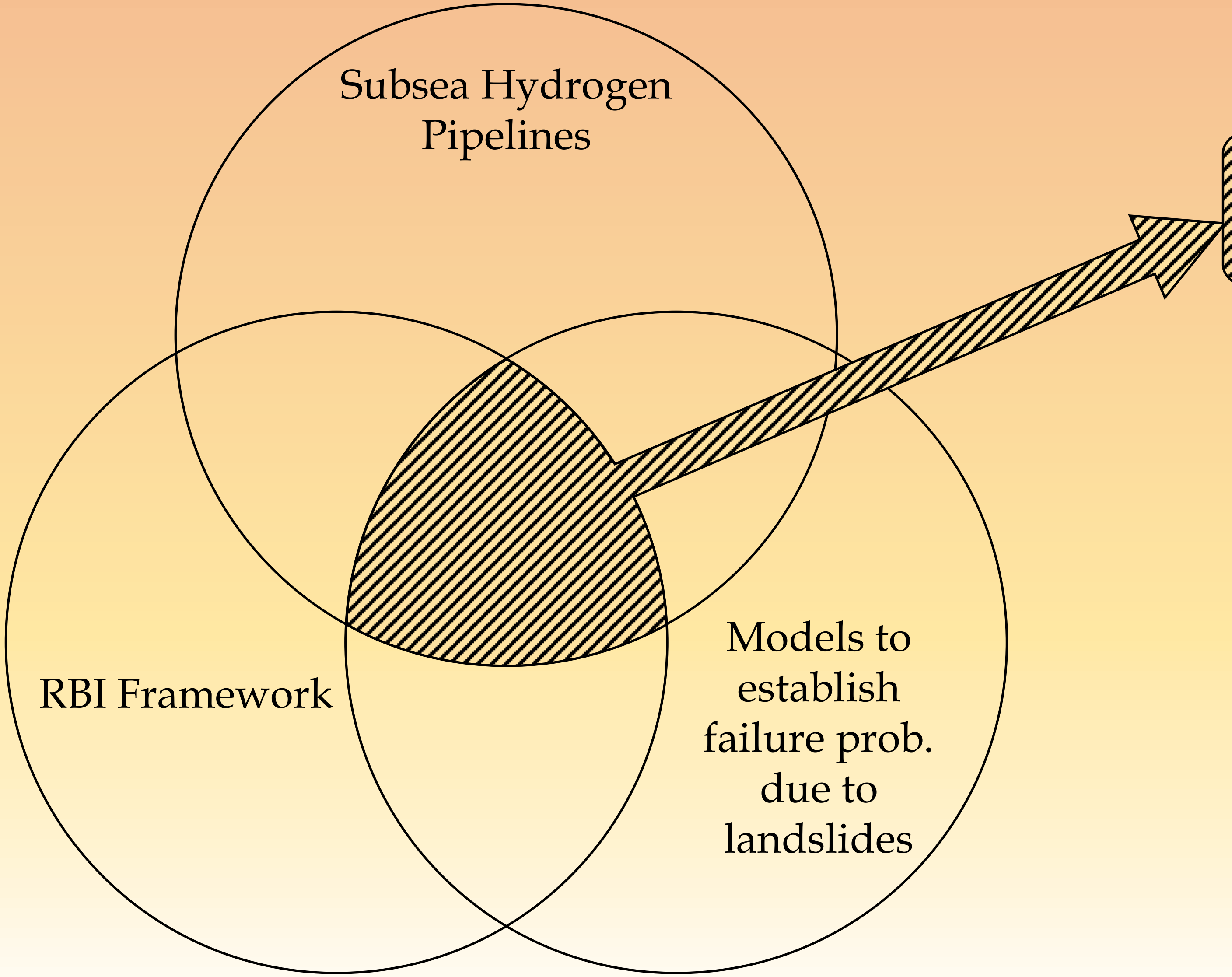

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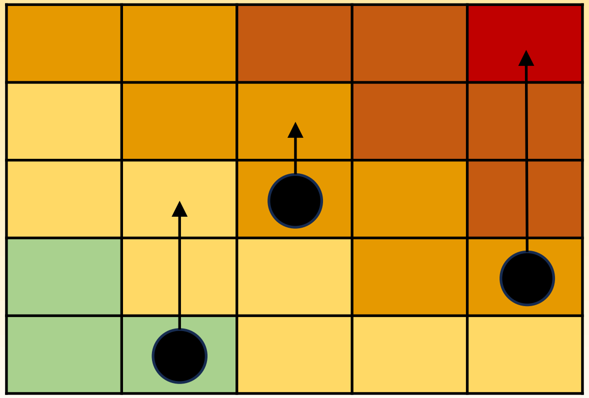

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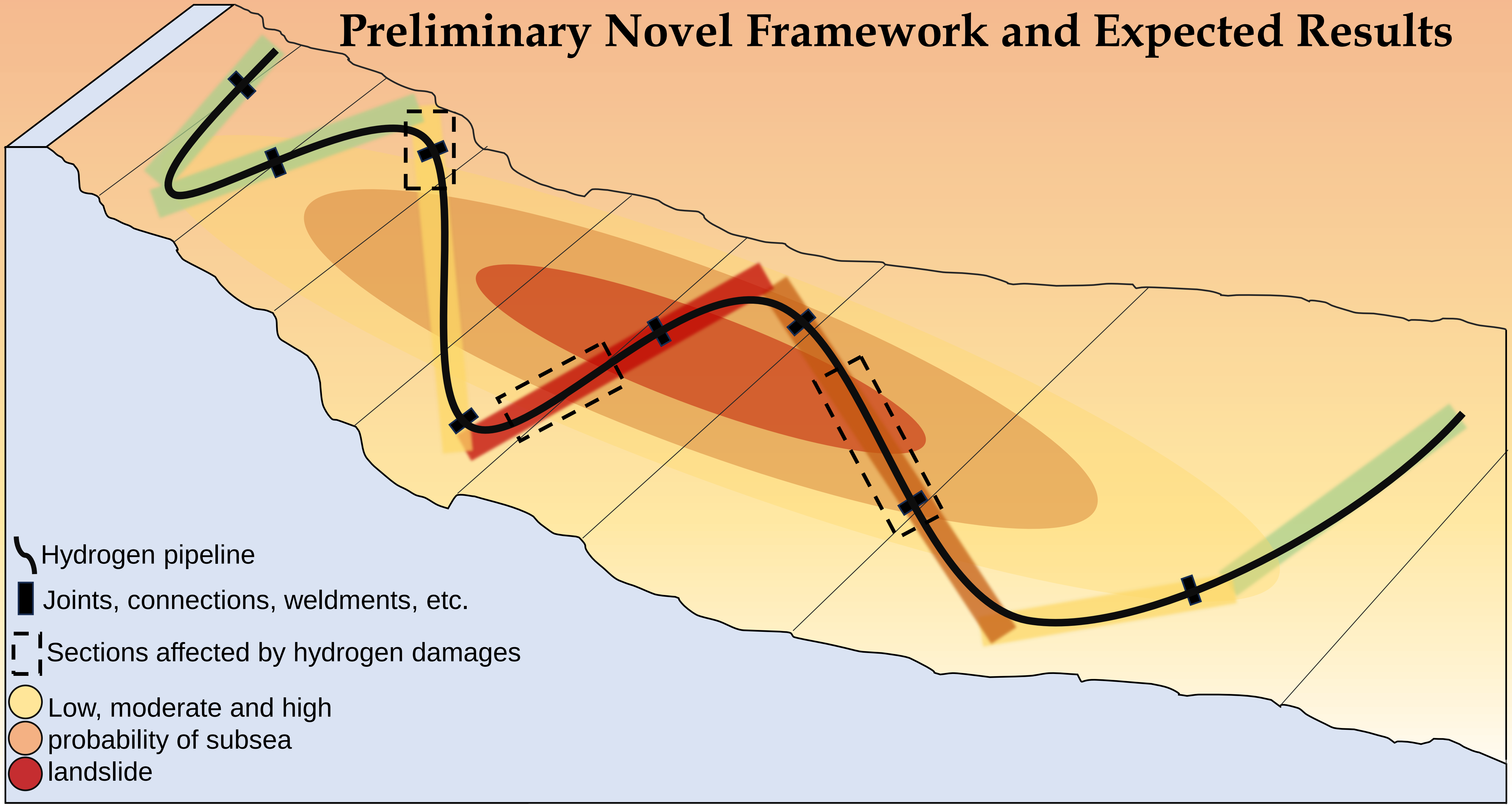


Conclusion and Limitations

Exploration of the potential support that a Natech-oriented RBI methodology may provide to the operational safety of subsea hydrogen pipelines.

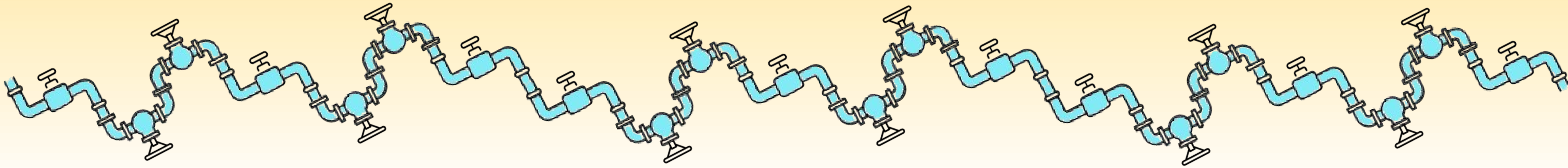
Definition of a preliminary approach for the risk calculation that considers both material degradation and exposure to natural hazards.

Outline the potential results obtainable with this framework.

Conclusion and Limitations

RBI (American Petroleum Institute, 2019) was developed to deal with hazardous substances and material integrity rather than external factors, so a thorough investigation of its applicability to Natech-risk management should be conducted.

Natech events could be extremely consequence-oriented (low probability – high impact (Nascimento and Alencar, 2016)) and the proposed approach (based on probability) may disregard this aspect.



THANK YOU FOR THE ATTENTION!

QUESTIONS?

Can also contact me at
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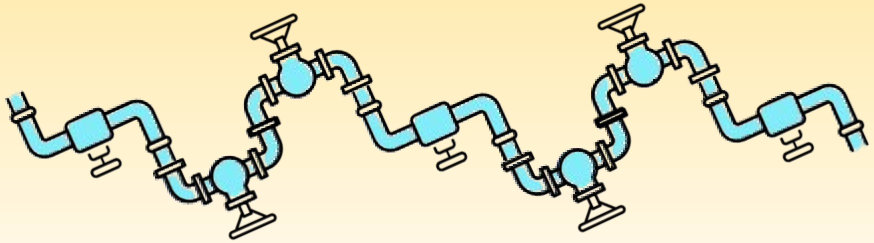

References

- Alvarado-Franco, J.P., Castro, D., Estrada, N., Caicedo, B., Sánchez-Silva, M., Camacho, L.A., Muñoz, F., 2017. Quantitative-mechanistic model for assessing landslide probability and pipeline failure probability due to landslides. Engineering Geology 222, 212–224. https://doi.org/10.1016/j.enggeo.2017.04.005
- American Petroleum Institute, 2019. API Recommended Practice 581, Risk-Based Inspection Methodology.
- American Petroleum Institute, 2016. API Recommended Practice 580, Risk-Based Inspection.
- Anderson, T.L., 2005. Fracture Mechanics: Fundamentals and Applications.
- Badida, P., Balasubramaniam, Y., Jayaprakash, J., 2019. Risk evaluation of oil and natural gas pipelines due to natural hazards using fuzzy fault tree analysis. Journal of Natural Gas Science and Engineering 66, 284–292. https://doi.org/10.1016/j.jngse.2019.04.010
- Campari, A., Ustolin, F., Alvaro, A., Paltrinieri, N., 2023. A review on hydrogen embrittlement and risk-based inspection of hydrogen technologies. International Journal of Hydrogen Energy S0360319923027106. https://doi.org/10.1016/j.ijhydene.2023.05.293
- Hagen, A.B., Alvaro, A., 2020. Hydrogen Influence on Mechanical Properties in Pipeline Steel - state of the art (No. 978-82-14- 06311– 0). SINTEF Industry / Materials and Nanotechnology.
- Laureys, A., Depraetere, R., Cauwels, M., Depover, T., Hertelé, S., Verbeken, K., 2022. Use of existing steel pipeline infrastructure for gaseous hydrogen storage and transport: A review of factors affecting hydrogen induced degradation. Journal of Natural Gas Science and Engineering 101, 104534. https://doi.org/10.1016/j.jngse.2022.104534
- Nascimento, K.R.D.S., Alencar, M.H., 2016. Management of risks in natural disasters: A systematic review of the literature on NATECH events. Journal of Loss Prevention in the Process Industries 44, 347–359. https://doi.org/10.1016/j.jlp.2016.10.003
- Qian, X., Das, H.S., 2019. Modeling Subsea Pipeline Movement Subjected to Submarine Debris-Flow Impact. J. Pipeline Syst. Eng. Pract. 10, 04019016. https://doi.org/10.1061/(ASCE)PS.1949-1204.0000386
- Song, S., Hua, W., Luo, X., Cruz, A.M., 2023. Methodology for assessing pipeline failure probability due to a debris flow in the near field. Heliyon 9, e15956. https://doi.org/10.1016/j.heliyon.2023.e15956