Integrating Human and Organisational Factors into Prognostics and Health Management Framework for Wind Farms

Arvind Keprate[1], Stine S. Kilskar[2]

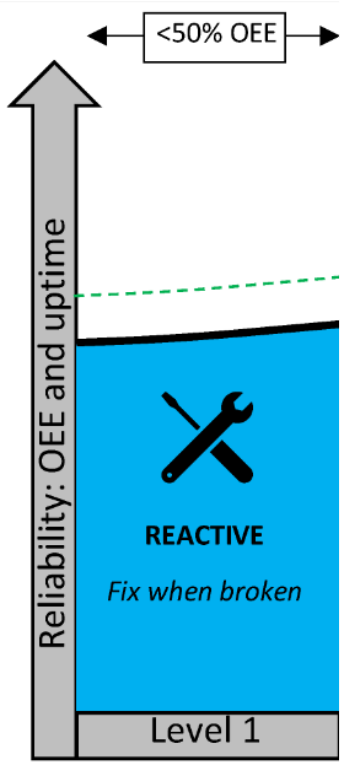
1. GreenMet Lab, Department of Mechanical, Electrical and Chemical Engineering, OsloMet, Oslo, Norway
2. Department of Software Engineering, Safety and Security, SINTEF Digital, Trondheim, Norway.

EERA DeepWind CONFERENCE 2024

Maintenance Evolution

1940	• Breakdown Maintenance	Level 1
1960	• Preventive Maintenance	Level 2
1970	• Safety Factor Based Maintenance	
1980	• Reliability Centered Maintenence	
1990	• Total Production Maintenance	
2000	• Condition/Risk Based Maintenance	Level 3
2010	• Risk Based Design/Integrity Maintenance	
2020	• Real-time Monitoring and Maintenance	Level 4

Ref : 1.



OEE: Overall Equipment Effectiveness

Ref : 2.

Condition Monitoring (Level 3)

Condition monitoring (CM) is the process of monitoring a particular condition in machinery (such as vibration, temperature, etc.) to identify changes that could indicate a developing fault.

Condition Monitoring - Humans

Image Source: Canva

Condition Monitoring - Machines

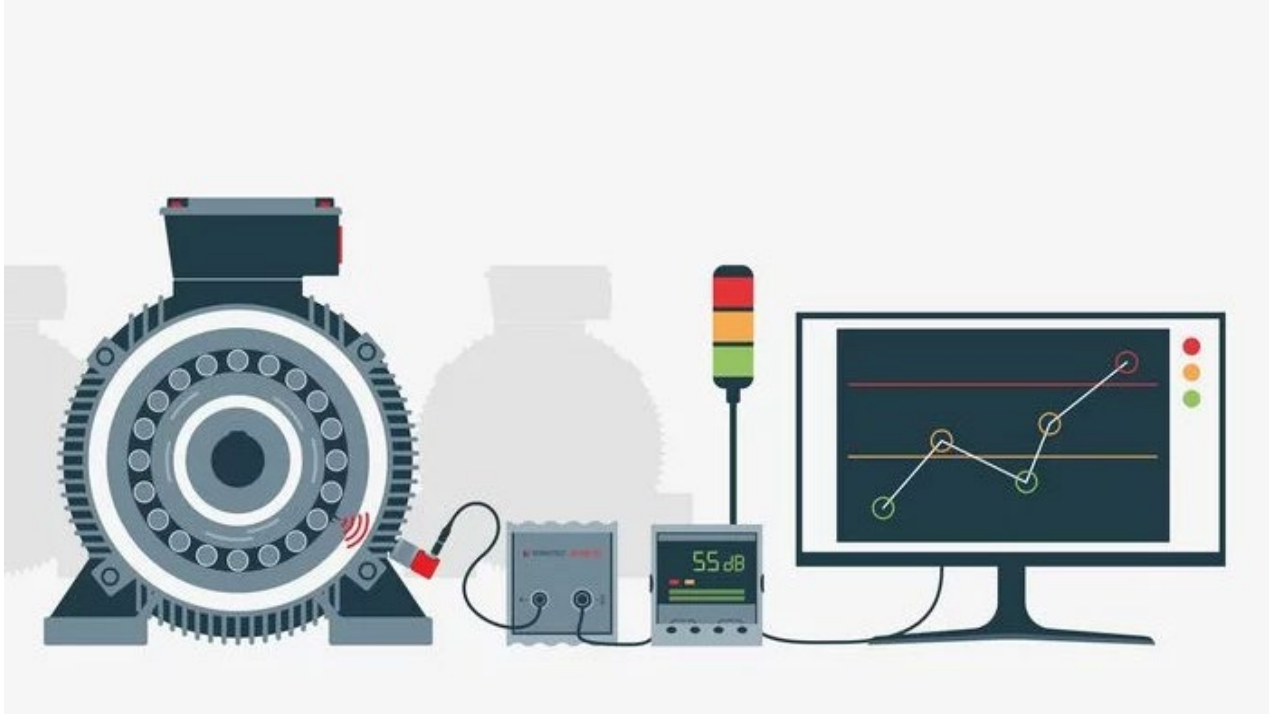


Image Source: https://www.sonotec.eu/

Condition Monitoring Methods

Offline Methods

Real-Time

1950s-1970s
- Visual Observation
- Auditory Inspection
- Thermography

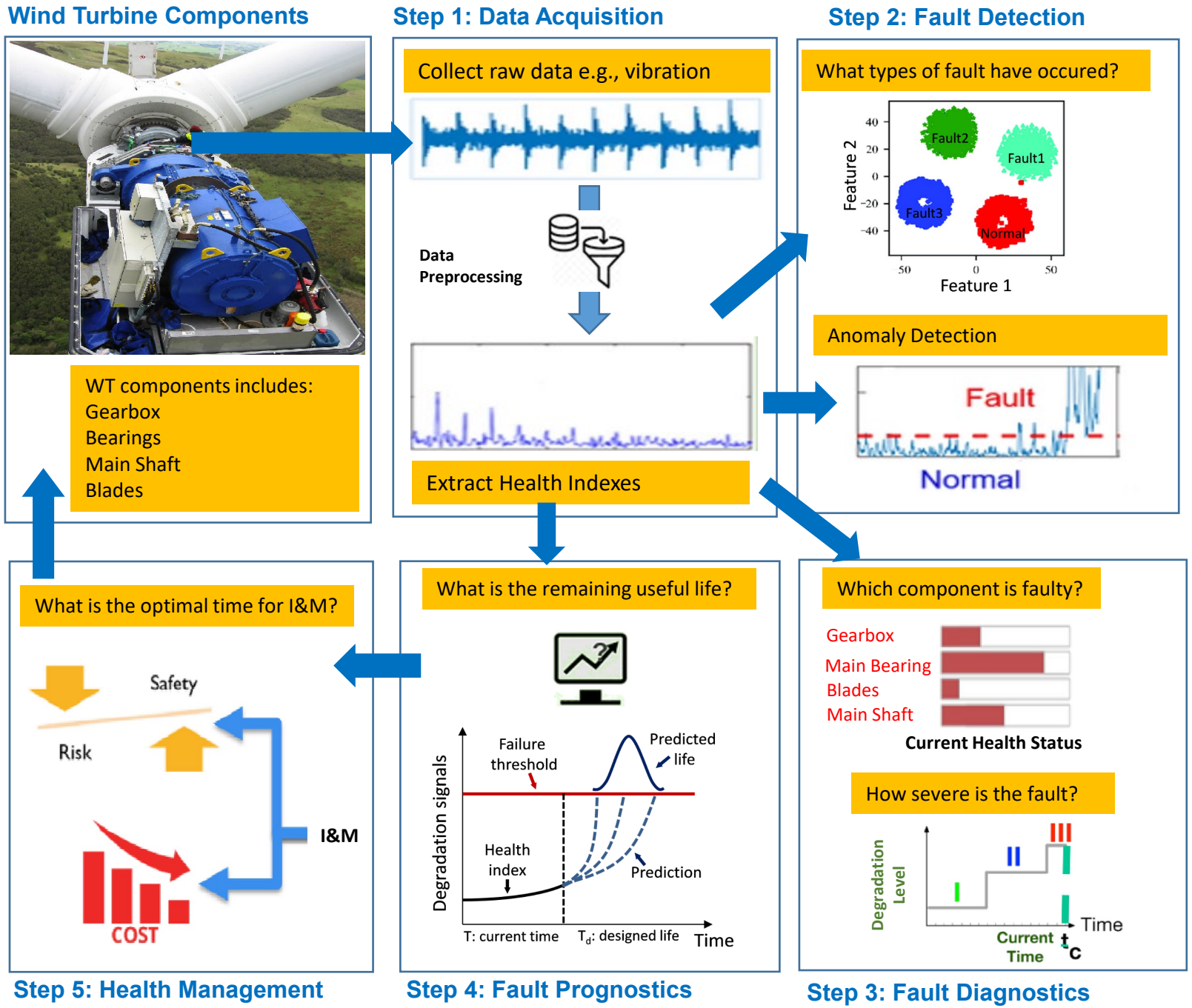
1980s-1990s
- Ultrasoncis
- Shock Pulse Method
- Motor Current Analysis

Condition Monitoring Methods Evolution

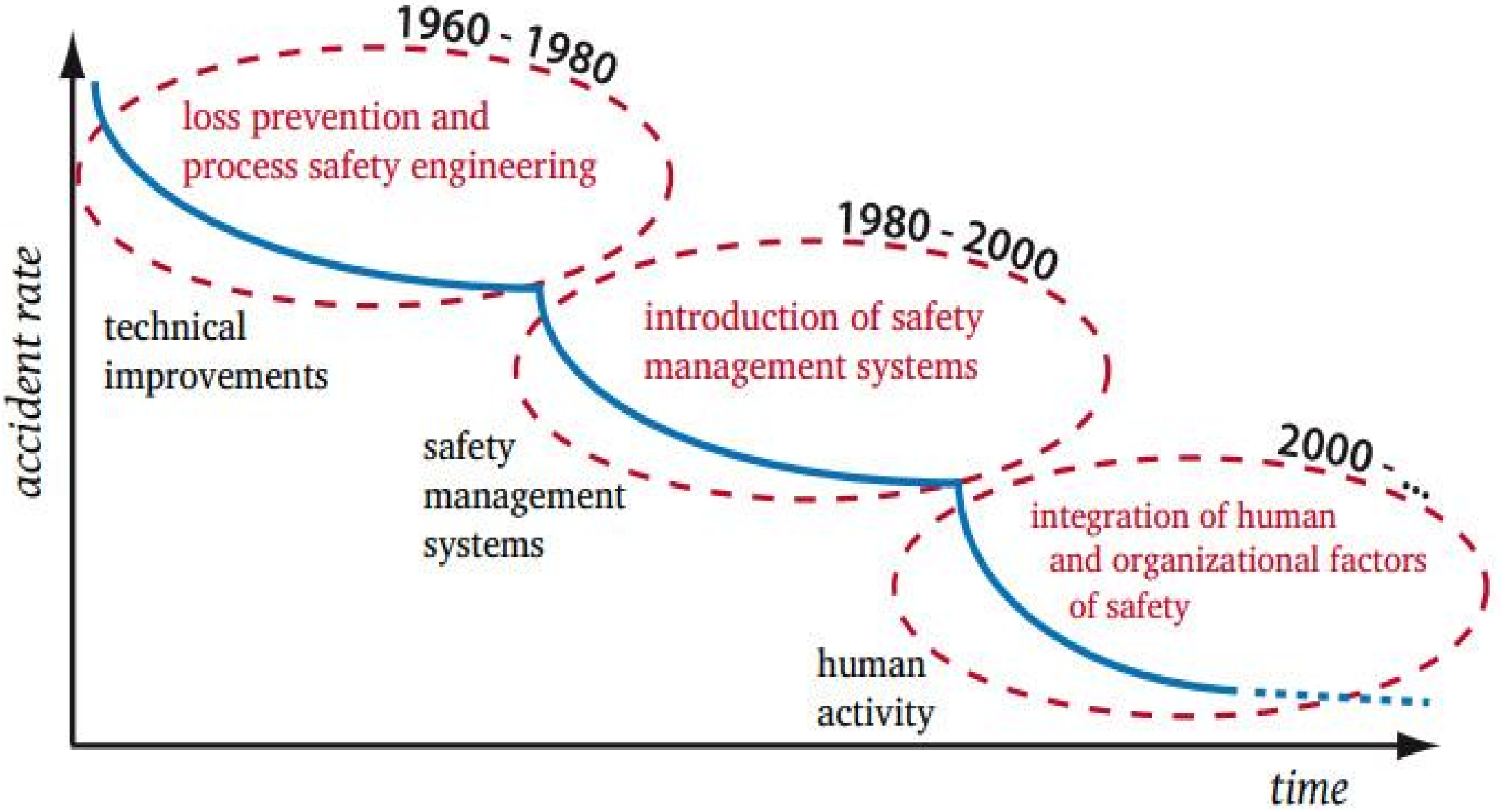
1960s-1970s
- Oil Analysis
- Vibration Analysis with FFT analyzers
- Signature Analysis

Current PHM Framework of WTs (Level 4)

- **Main focus is on machine related data.**
- **40% of failures in WT industry are due to human related errors.**
- An overburdened technician might miss subtle indications of wear, leading to unexpected equipment breakdowns.
- Similarly, a company emphasizing proactive maintenance is likely to prioritize regular training, resulting in reduced operational mistakes.



Factors Responsible for Reducing Accident Rate in High-Risk Industries

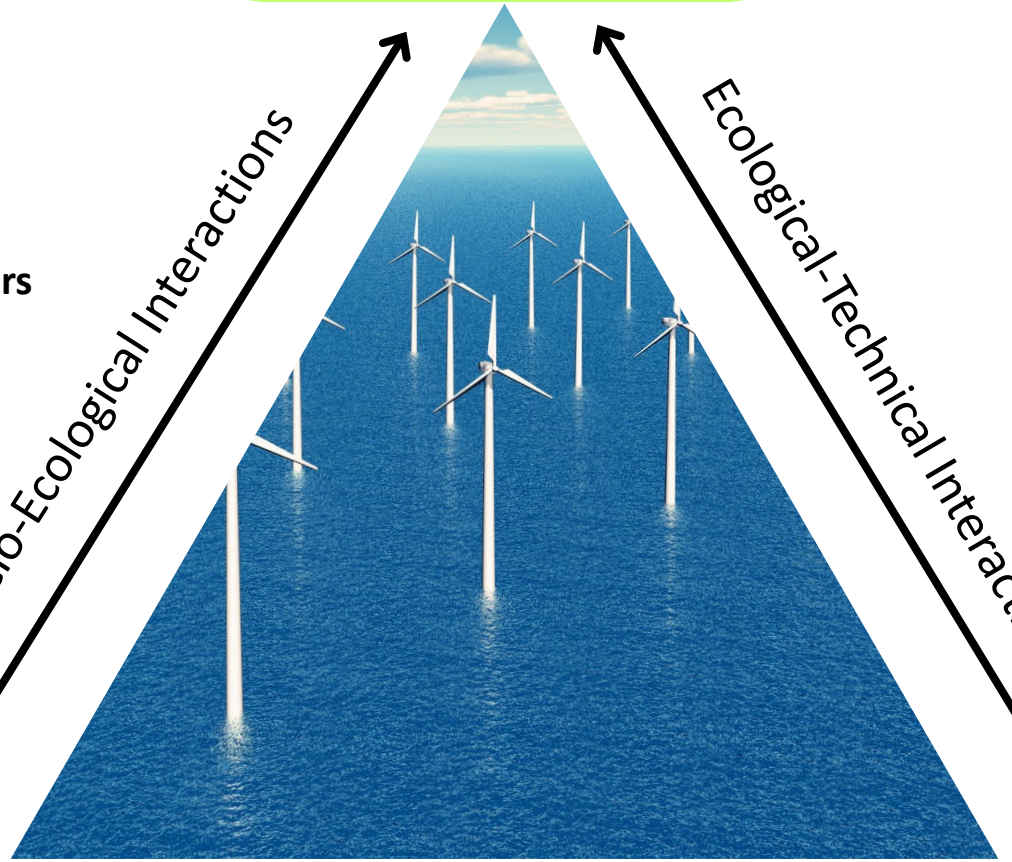


Ref : 3.

Wind Farms as Socio-Ecological-Technical Systems (SETS)

Following Knowledge Gaps in PHM as per SETS:

- **Lacking Societal Dimension (S-Perspective)**
- **Neglecting Ecological Elements (E-Perspective)**
- **Non-inclusion of Human and Organizational Factors (T-Perspective)**



Human and Organizational Factors (HOFs)

HOFs refer to the aspects of human behavior and organizational structures that impact performance, safety, and efficiency in the workplace.

Ref : 4.

Performance Shape Factors (PSFs)

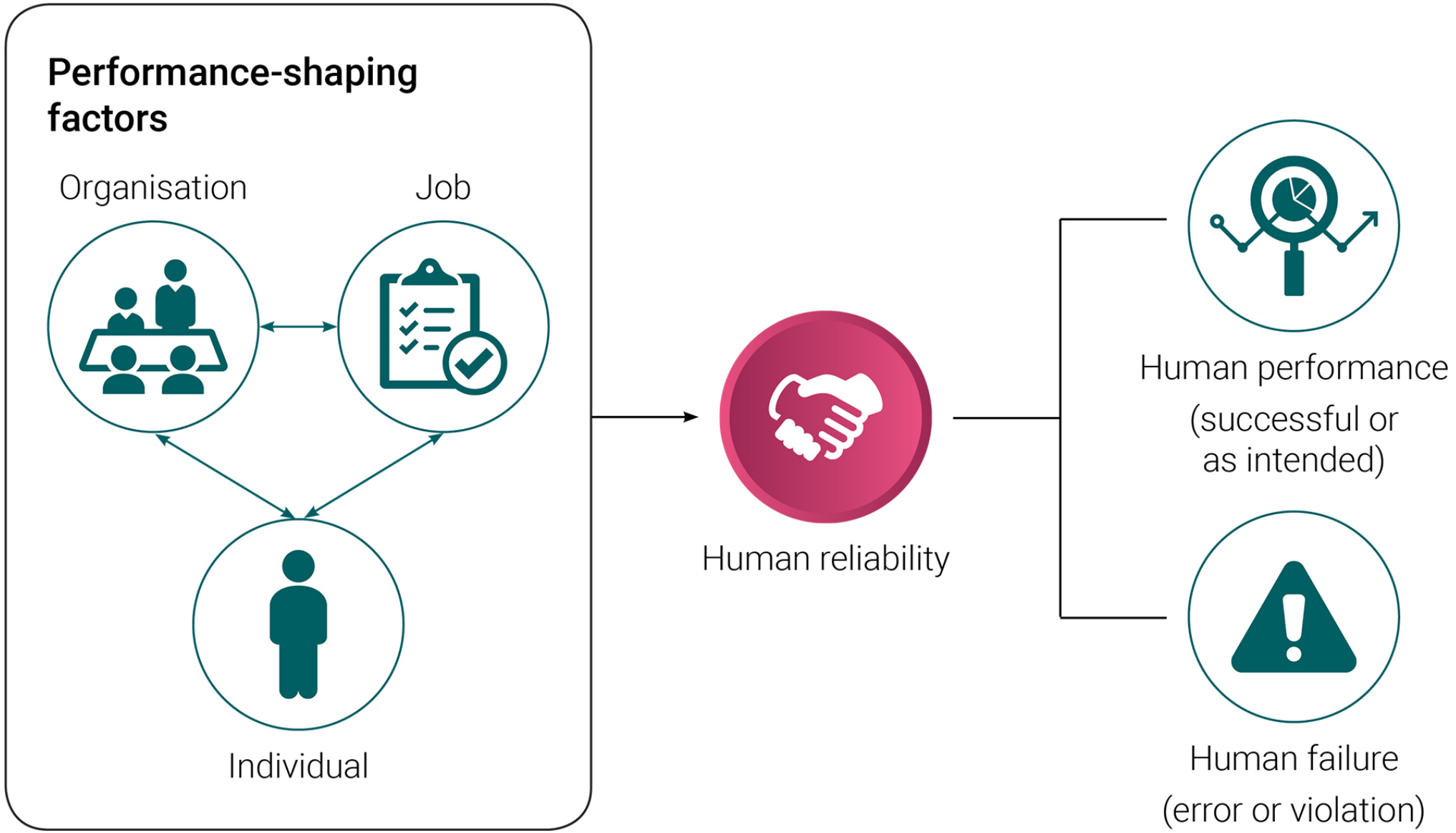
PSFs are elements that influence or 'shape' human performance, especially in work environments. These factors can be categorized into three main areas:

Job-related Factors: These include the difficulty or complexity of tasks, the time available to perform these tasks, and the physical work environment in which the tasks are performed.

Individual-related Factors: These encompass the physical capability and condition of the individual, levels of stress, amount of knowledge, expertise level, and personal motivation.

Organization-related Factors: These refer to the clarity of roles and responsibilities within the organization, the level of supervision provided, and the overall workplace culture.

Performance Shape Factors (PSFs) and Human Reliability



Ref : 4.

Human Errors and Behaviour

Human error occurs due to actions that inadvertently deviate from expected or optimal human behavior. Three different types of behaviour:

Skill-Based Behaviour: These are tasks that are simple and routine and have been carried out many times before. Attention required for the task is minimal, with the person effectively running on autopilot. Although basic progress checks are performed from time to time, these checks are largely subconscious.

Rule-Based Behaviour: Rules are applied to tasks to either help work through a problem or to identify the correct action to take. The rules may be stored in our memory or in the form of written instructions.

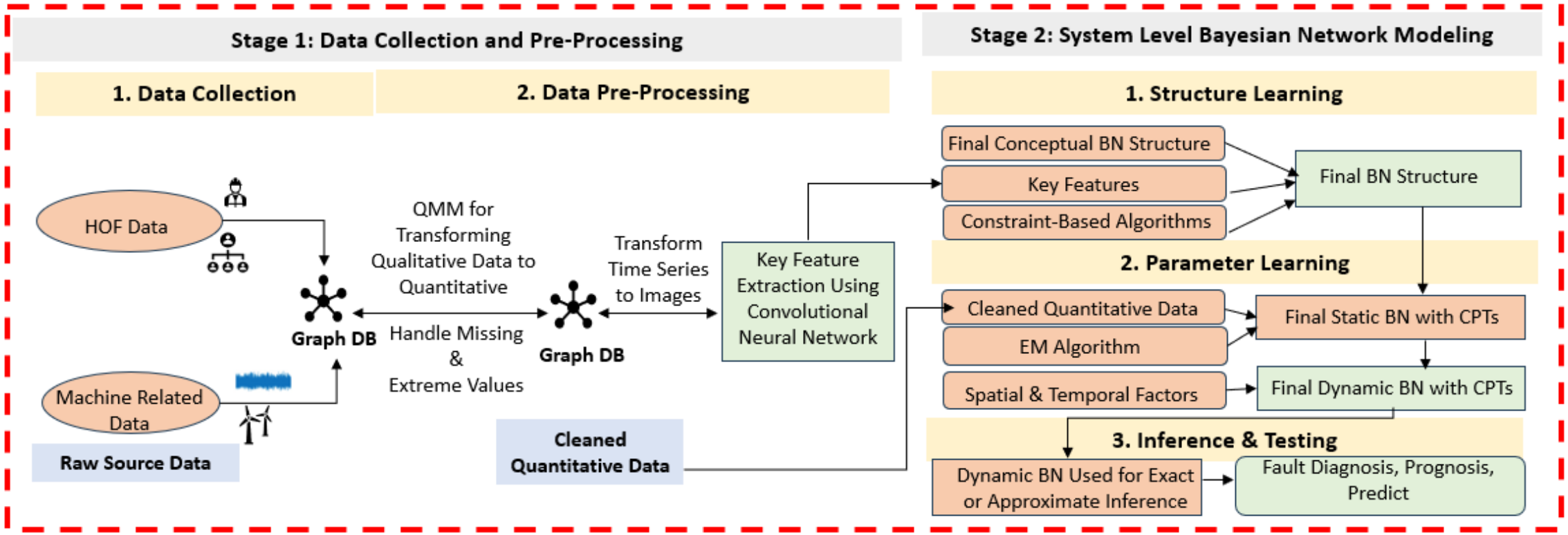
Knowledge-Based Behaviour: Knowledge-based behaviour is usually applicable in problem-solving or troubleshooting tasks and demands significant conscious effort when our rules no longer apply. This is when a solution to an issue is devised based on knowledge, experience and a ‘mental model’ of how the system works.

Our Approach

1. Identify and populate various maintenance tasks: Use maintenance records and Natural Language Processing.

2. Categorize various maintenance tasks into skill-based, rule-based, or knowledge-based. Use Sentiment Analysis and Supervised Learning.

3. Perform Human Reliability Analysis (HRA) to identify potential human failure events (HFEs) and systematically estimate the probability of those events using data, models, or expert judgment. Use the Bayesian Network as a tool to estimate the probabilities.



Reference

1. Çınar, Z. M., Abdussalam Nuhu, A., Zeeshan, Q., Korhan, O., Asmael, M., & Safaei, B. (2020, October 5). Machine Learning in Predictive Maintenance towards Sustainable Smart Manufacturing in Industry 4.0. *Sustainability*, *12*(19), 8211.

2. Khan, F., Thodi, P., Imtiaz, S., & Abbassi, R. (2016, November). Real-time monitoring and management of offshore process system integrity. Current Opinion in Chemical Engineering, 14, 61–71.

3. Human and Organisational Factors (HOF). (2019, November 14). European Union Agency for Railways. https://www.era.europa.eu/domains/safety-management/human-and-organisational-factors-hof_enfuture. Eur. Comm., p. 3.

4. https://www.dmp.wa.gov.au/Safety/Human-and-organisational-21920.aspx.

Thanks For Your Attention