DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR OPTIMISED MAINTENANCE OF WIND TURBINES

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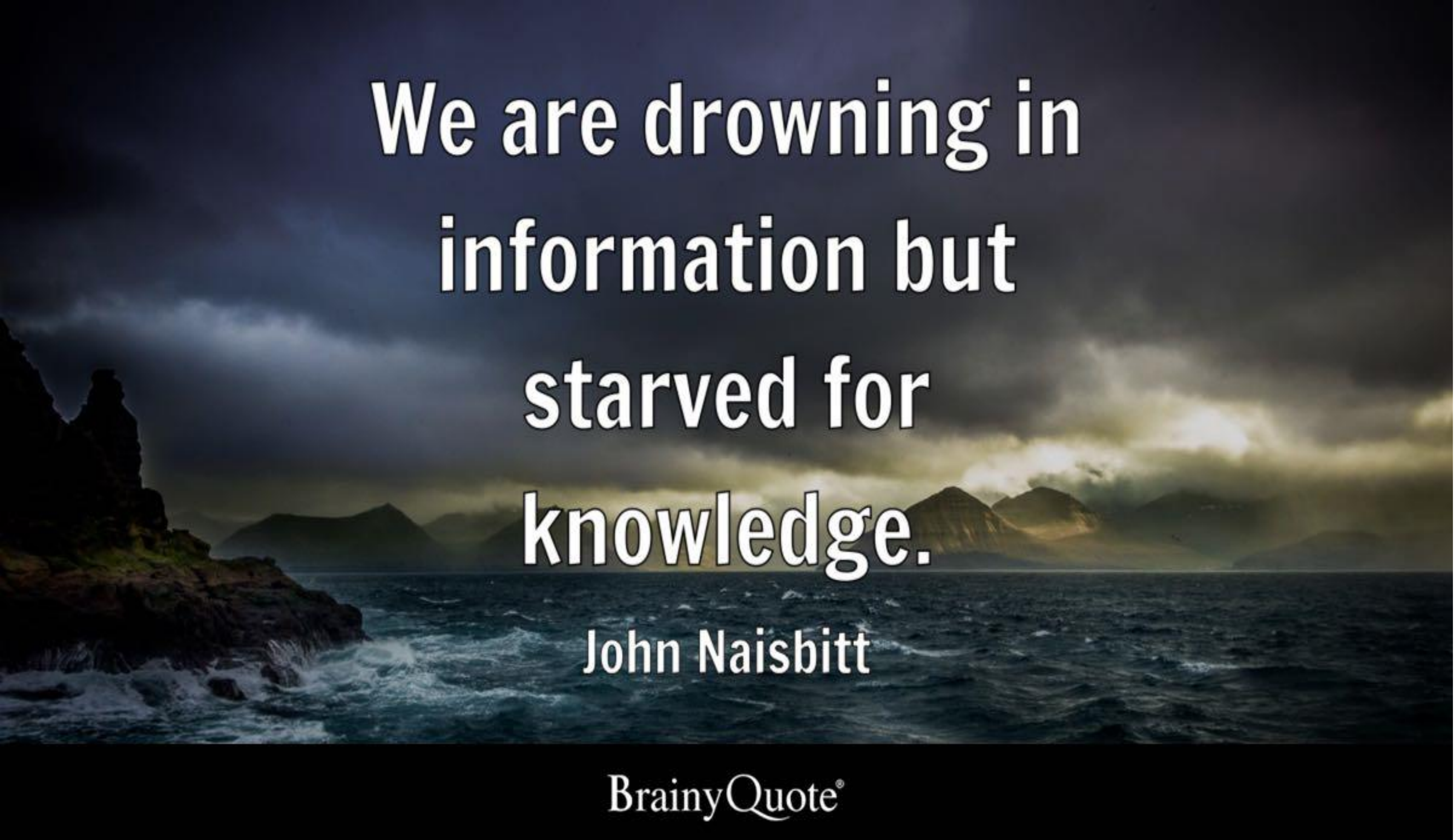
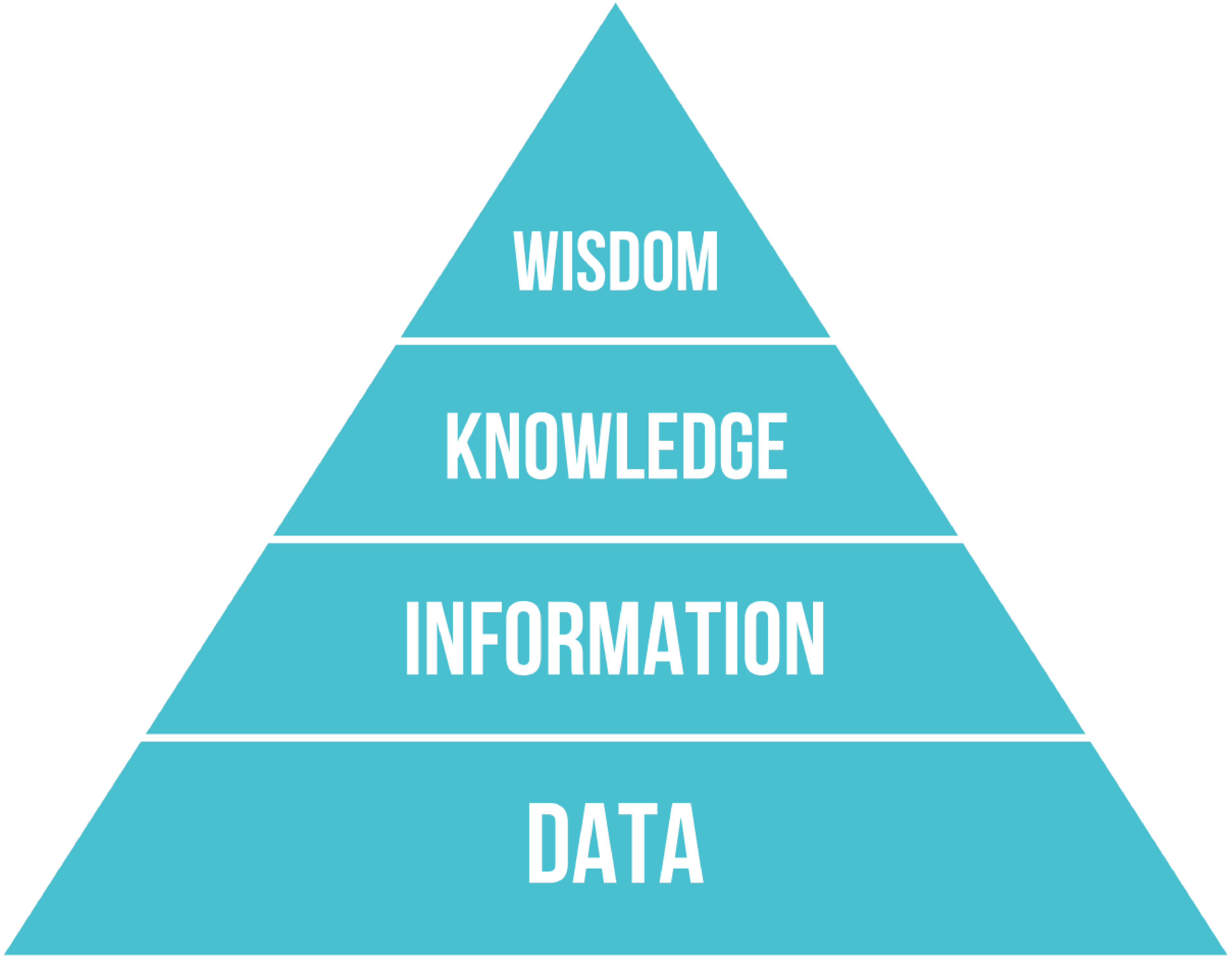

We are drowning in information but starved for knowledge.
John Naisbitt
BrainyQuote®

Core Idea

- Use of DIKW hierarchy for developing inspection / maintenance program for a wind turbine

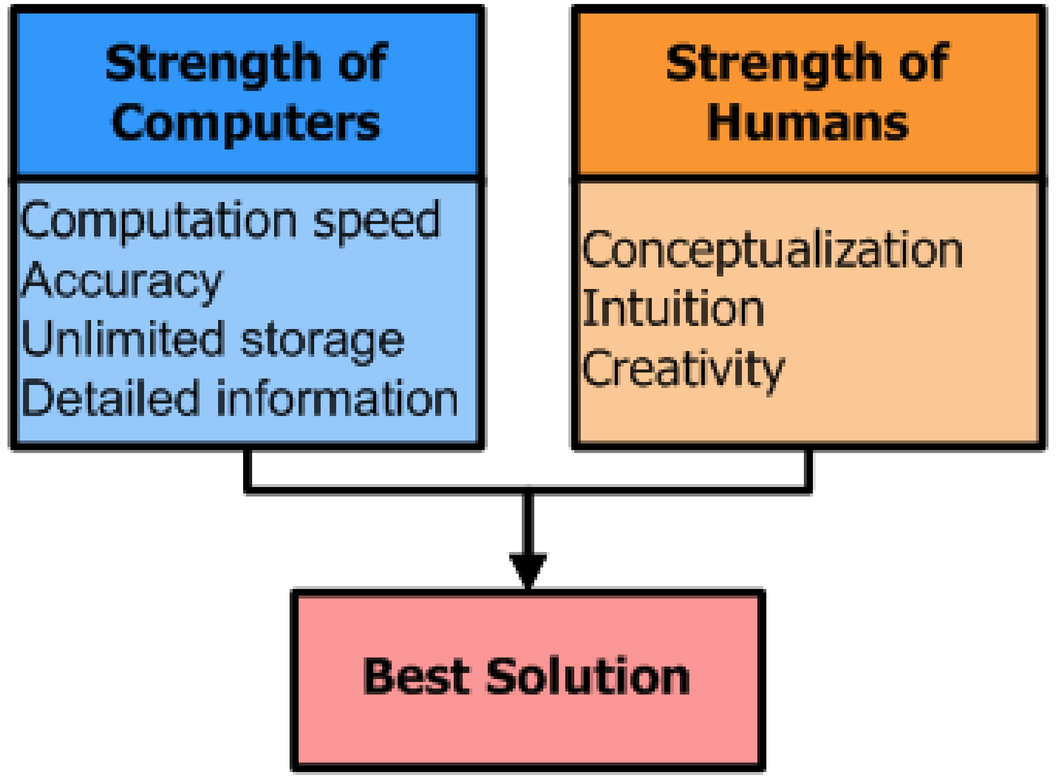


Høgskulen på Vestlandet

Abstract

❖Describes a proposed framework for an ***integrated decision support system*** that:

- integrates traditional (RBIM & RCM) and condition-based methods
- helps in preparing inspection-maintenance program for wind turbines
- is simple yet robust
- presentation of uncertainties and its implications.



❖Demonstrated using a use case of ***Generator Bearings in a Wind Turbine***

❖ ***Work in progress***

Høgskulen på Vestlandet

Identified Challenge

- Operation of **Wind Turbine** →

  Integrity of equipment (↓) →

  Probability of failure (↑).

- Monitoring & inspections →

  Knowledge about the condition →

  Directions for the future maintenance.

- Vast amount & imperfect data →

  Information overflow →

  Difficult to interpret

Høgskulen på Vestlandet

General Observations

- Requirement
  - *Data → Information → Knowledge → Decision*

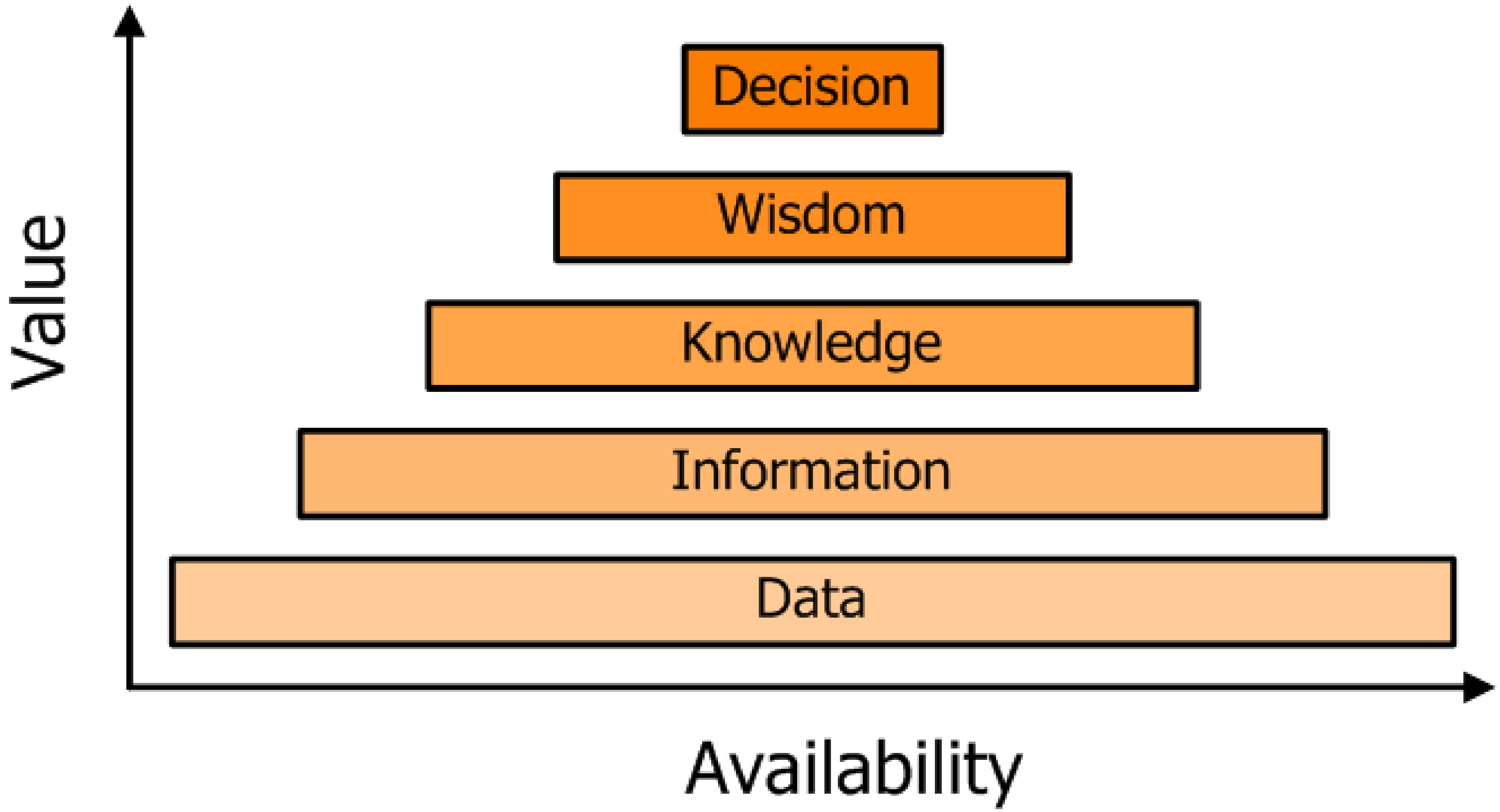
- Experience shows:
  - Vast amount of data is available
    - Data interpretation lags behind data collection-storage
    - Some data is not rational
    - Difficult to utilise all the available data to generate information
  - Information obtained from analysis often require expert interpretation
    - Not all information is turned to knowledge
  - Difficult to manipulate large amount of knowledge for taking optimised decision
    - Often not all knowledge used for during decision making

- Far more benefits and value can be accrued by proper integration of data with decision-making process

Aim of the Project

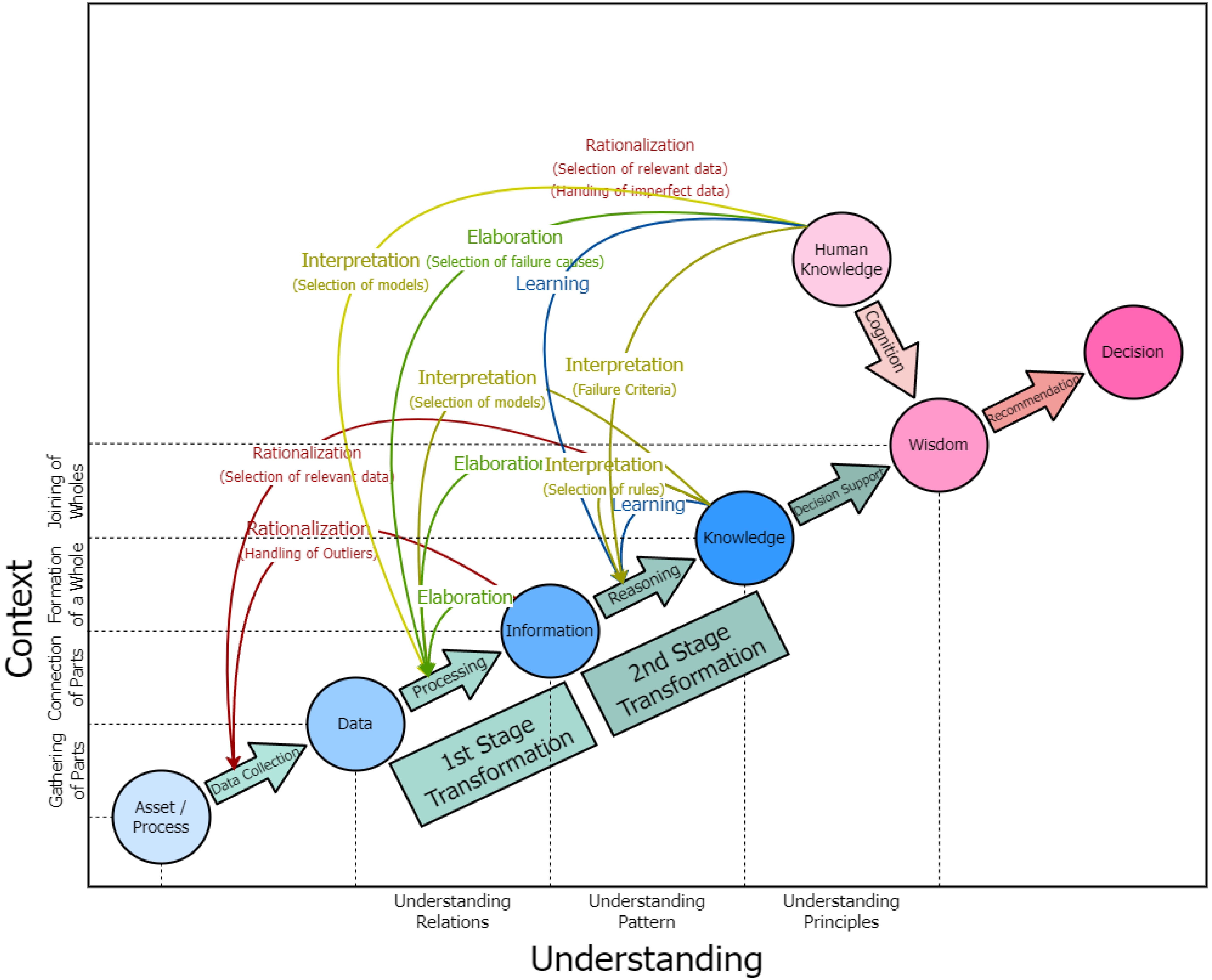
❖Develop a framework for a *human-centric* decision support system

- Help engineers get maximum value out of data
- Aid in developing maintenance program by proper use of data



OSLOMET

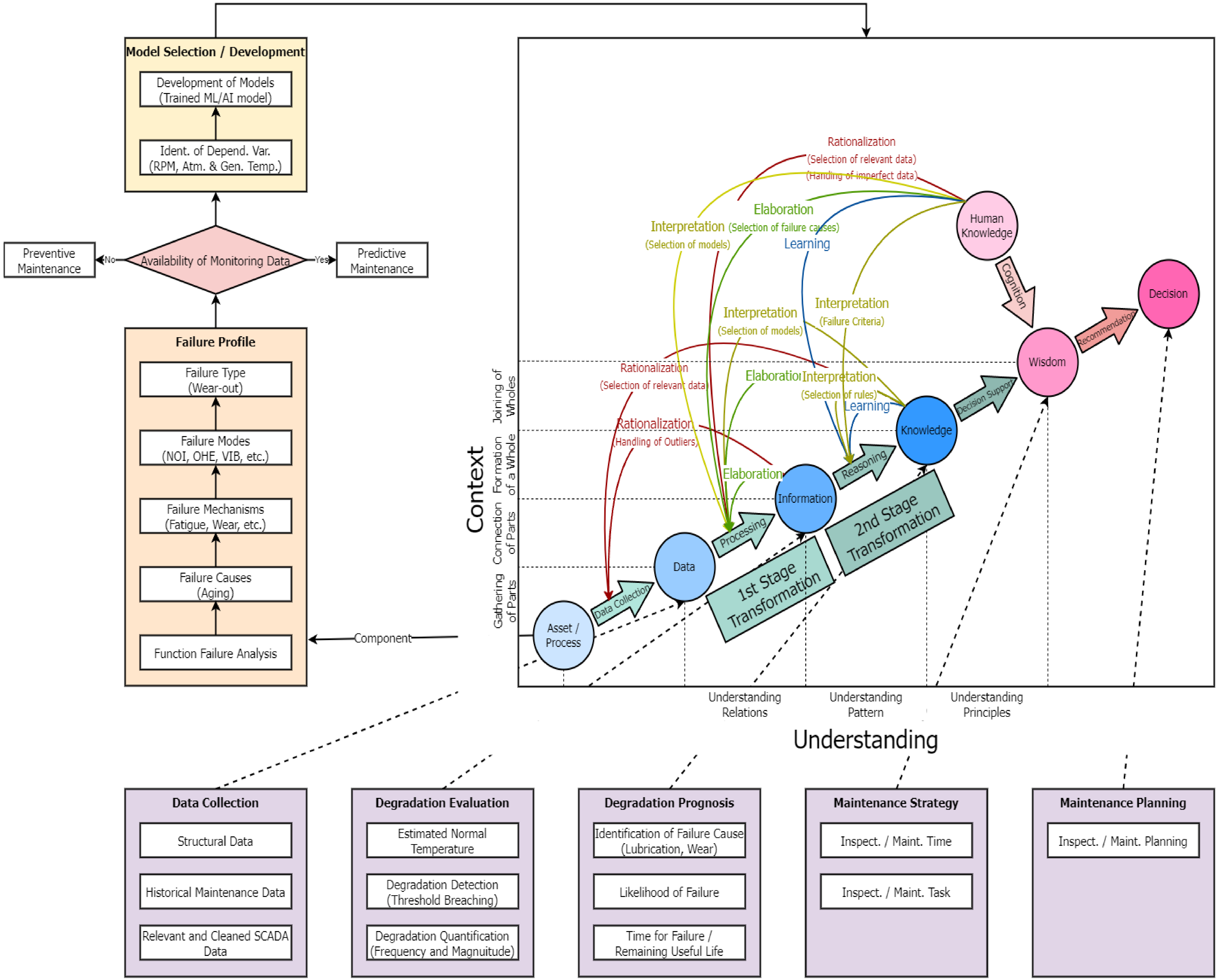
Transformation of Data to Decision



Høgskulen på Vestlandet

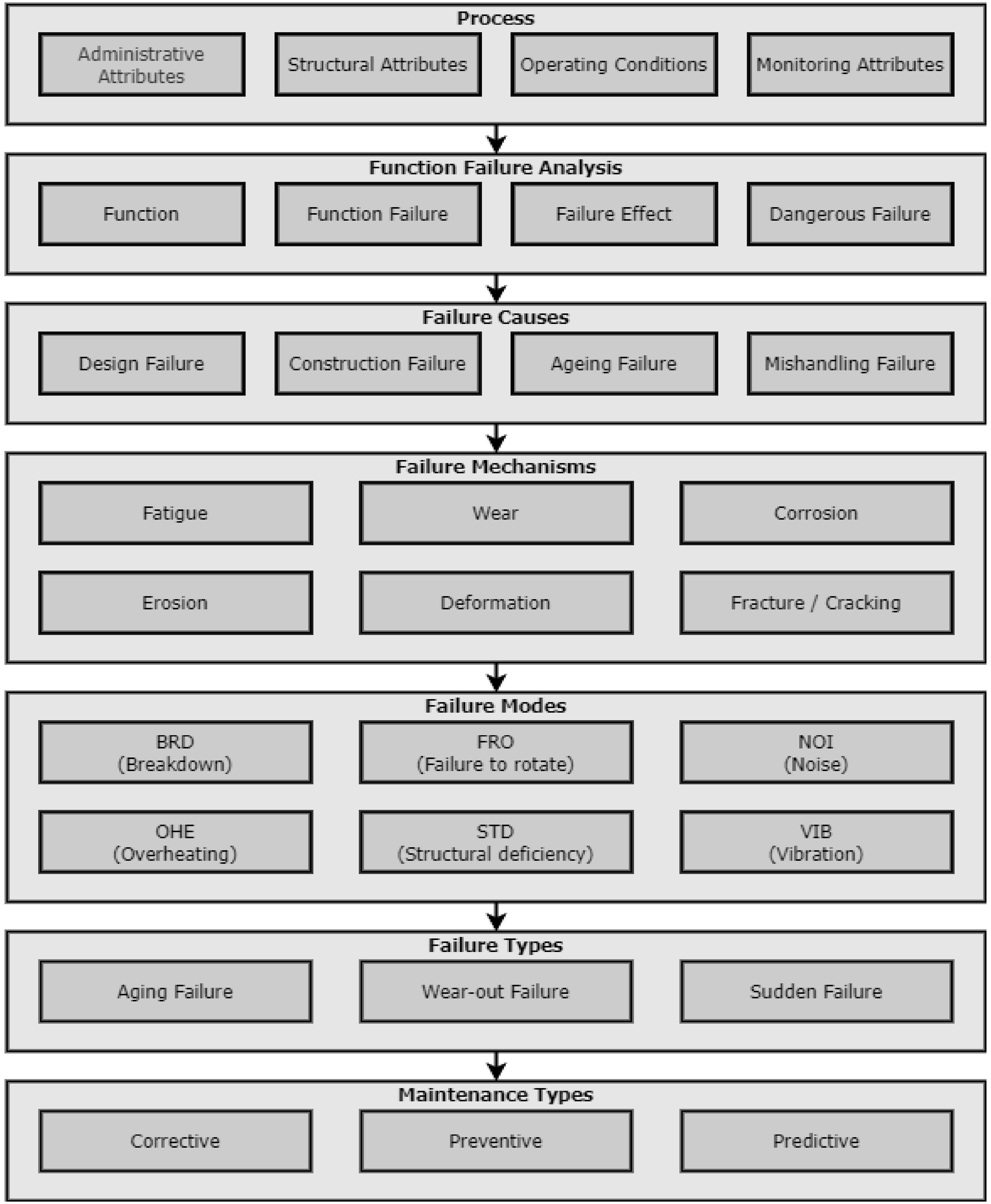
OSLOMET

Transformation of Data to Decision



Høgskulen på Vestlandet

Failure Profile of a Bearing



OSLOMET

Høgskulen på Vestlandet

Data Collection

Data is a raw attribute of real or simulated entities

- Process Design Parameters
  - Example, Material of Construction, Dimensions
- Process Operation Parameters
  - Example, Temperature (Bearing, Nacelle, Generator), RPM (bearing)
- Inspection Results
  - Example, NDT results
- Monitoring Data
  - Example, SCADA data

- Numerical and Measurement Based Data
  - Example: Bearing Temperature = 55.3^{o}C

Data Processing (1st Stage Transformation)

- ***Information*** represents the results of a computational process (interpreted data or data with meaning)
- Transform *data* (relevant, rationalized) into *information* (useful, reliable) using deterministic-probabilistic computations

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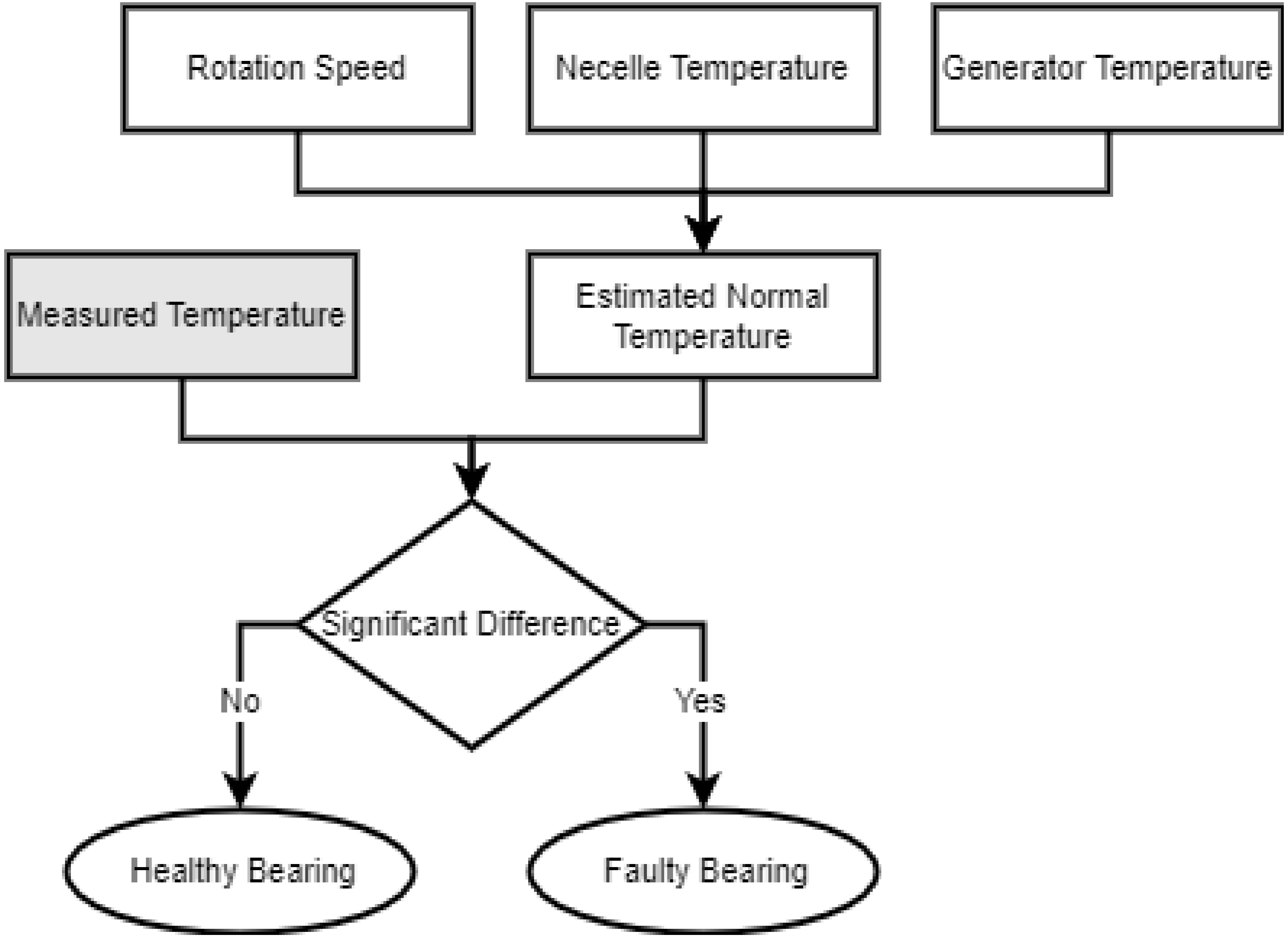
- Predicted Values
  - Example, Predicted Normal Bearing Temperature

- Fault Diagnostics
  - Example, Degradation Detection (Predicted Normal Bearing Temperature < Measured Temperature)
  - Example, Degradation Quantification (Frequency & Magnitude of Threshold Breaching)

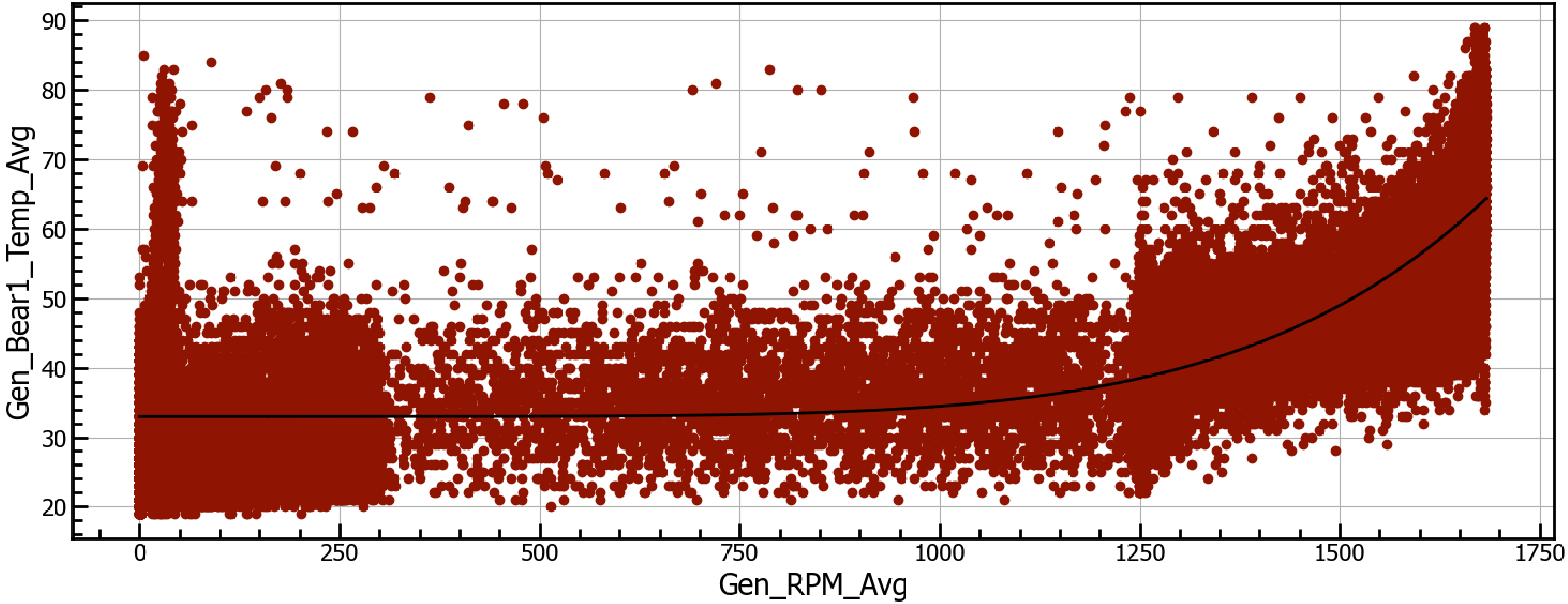
Høgskulen på Vestlandet

Methodology for Degradation Detection



Høgskulen på Vestlandet

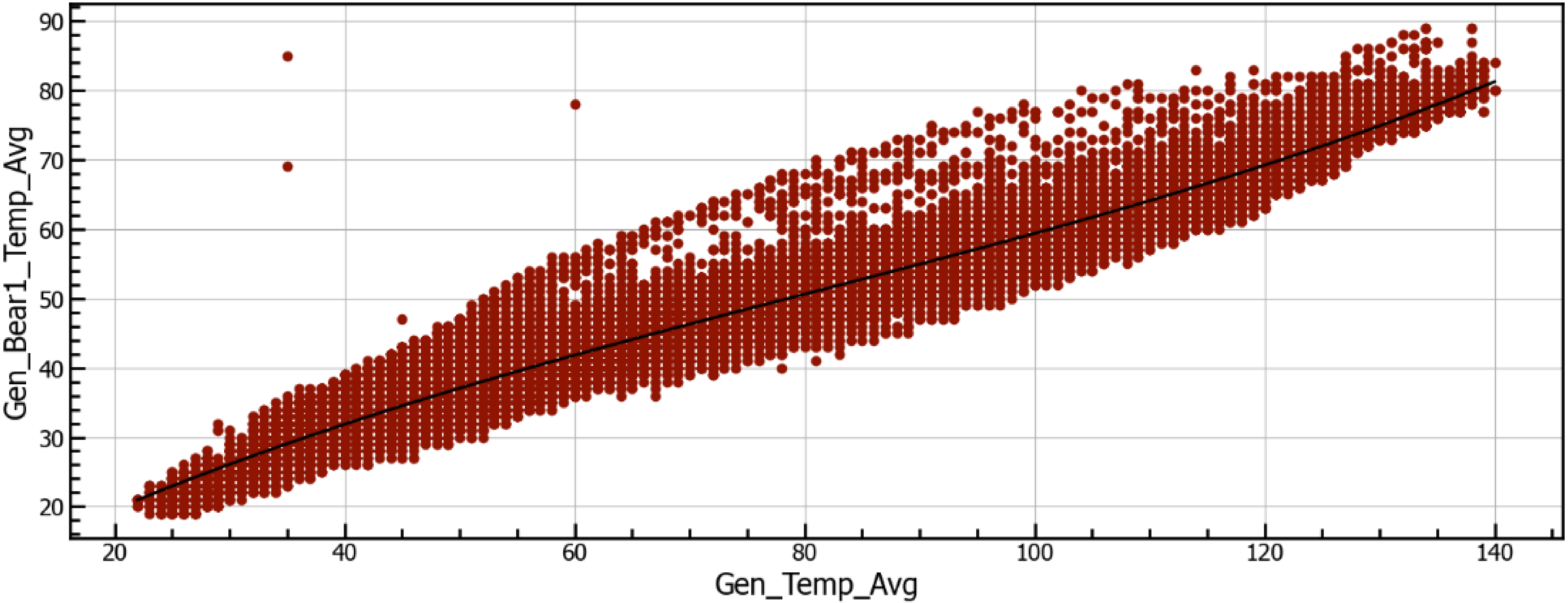
Effect of Shaft RPM on Temperature of Bearing 1



Høgskulen på Vestlandet

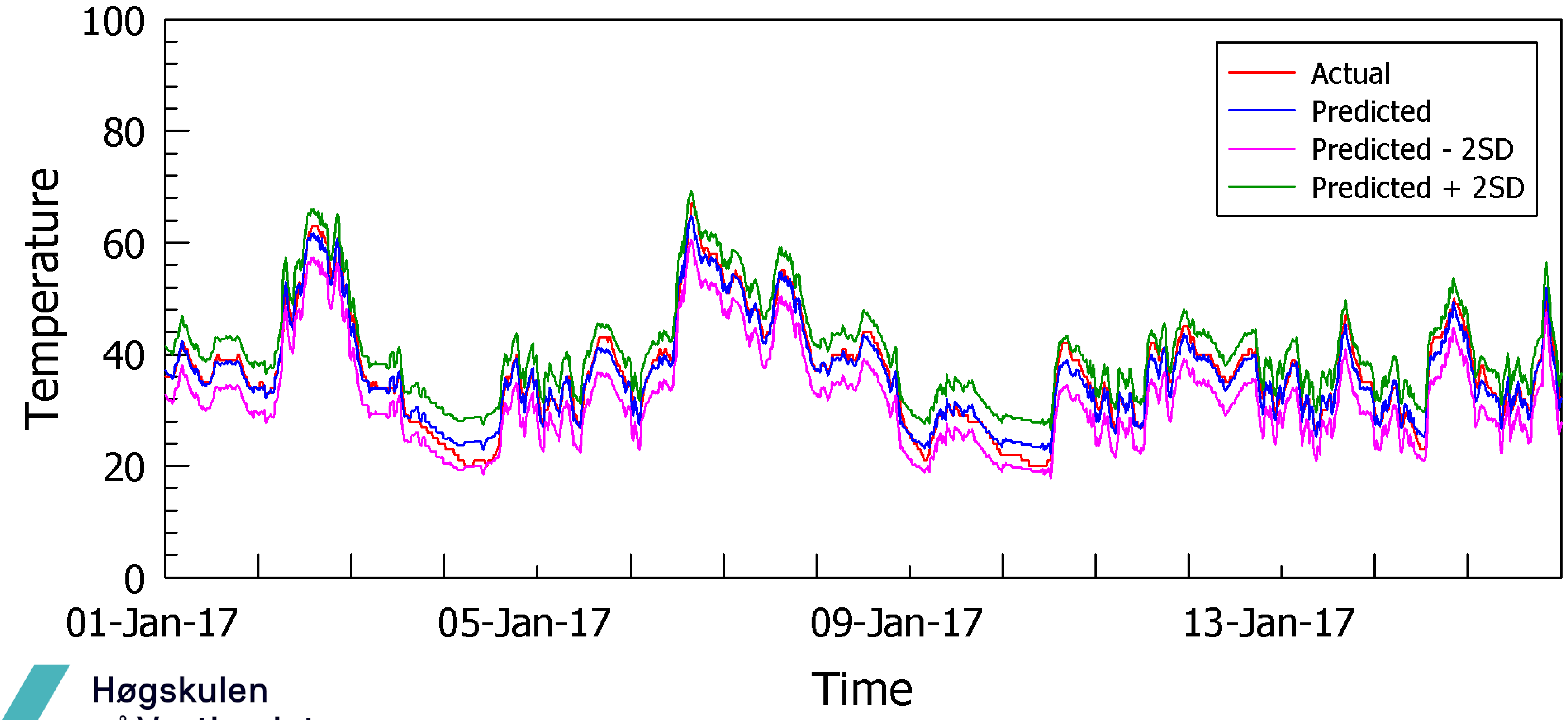
Effect of Generator Temperature on Temperature of Bearing 1

OSLOMET

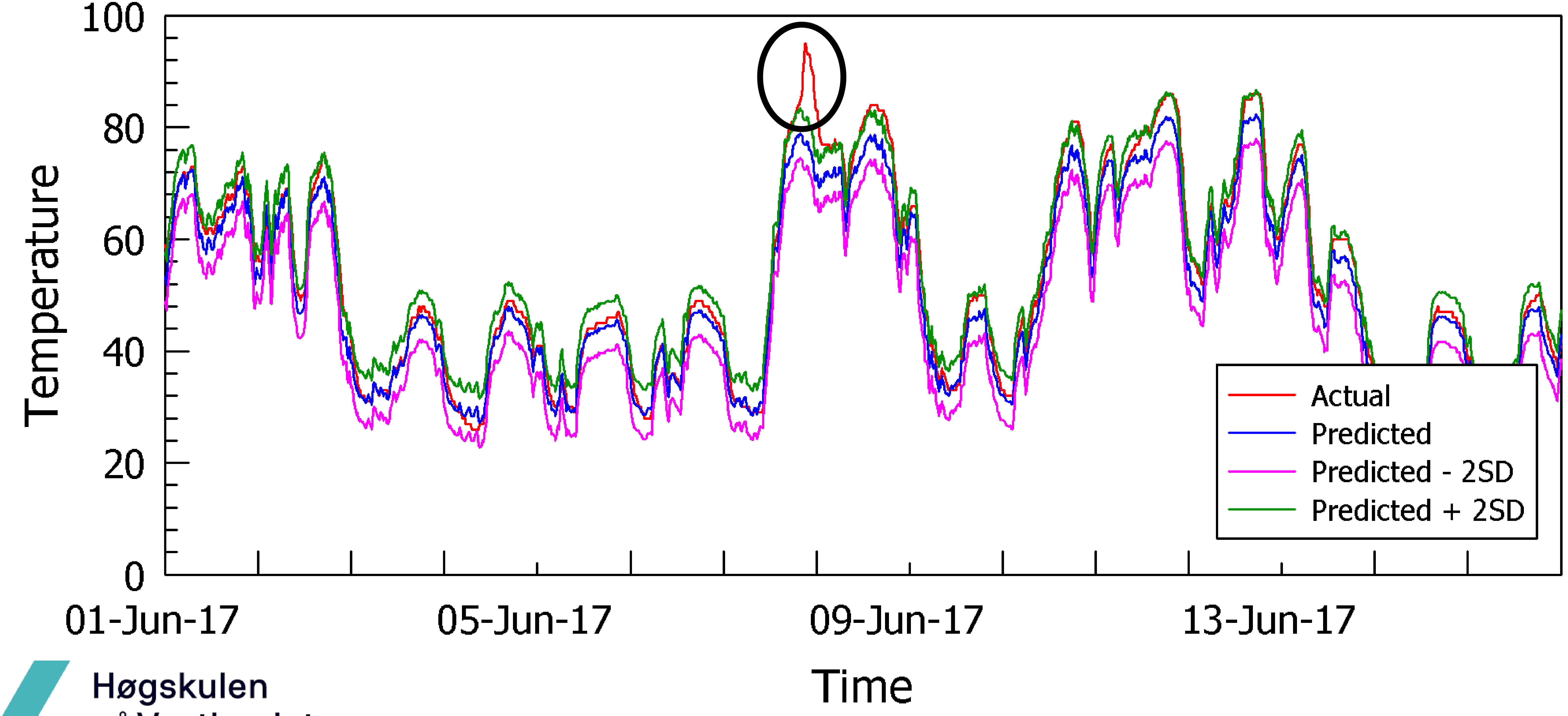


Høgskulen på Vestlandet

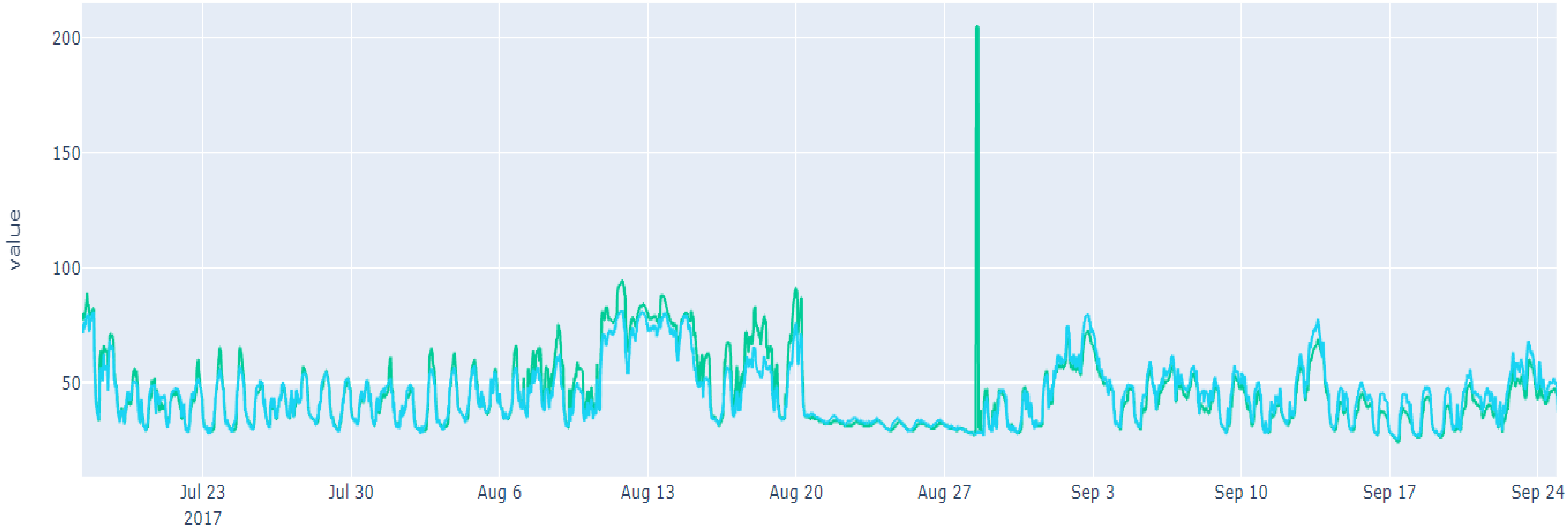
Actual and Predicted Temperatures of Bearing 1



Actual and Predicted Temperatures of Bearing 1



Actual and Predicted Temperatures of Bearing 2



Høgskulen på Vestlandet

Next is: Reasoning (2nd Stage Transformation)

- ***Knowledge*** is the data that represents the results of a computer-simulated cognitive process, such as reasoning, association, learning and perception

- Transform information into knowledge using non-deterministic soft-computing

$$\boldsymbol{IF}\ (Fault\_Quantification\ \boldsymbol{IS}\ High)\ \boldsymbol{THEN}\ (Remaining\_Useful\_Life\ \boldsymbol{IS}\ Short)$$

$$\boldsymbol{IF}\ (Remaining\_Useful\_Life\ \boldsymbol{IS}\ Short)\ \boldsymbol{THEN}\ (Next\_Maintenance\_Activity\ \boldsymbol{IS}\ Soon)$$

- Fault Prognosis
  - Example, Identification of Degradation Cause (Lubrication, Wear)
- Likelihood of Failure
  - Example, "Low", "Medium", "High"
- Remaining Useful Life
  - Example, "Short", "Medium", "Long"

Thanks for your attention ☺