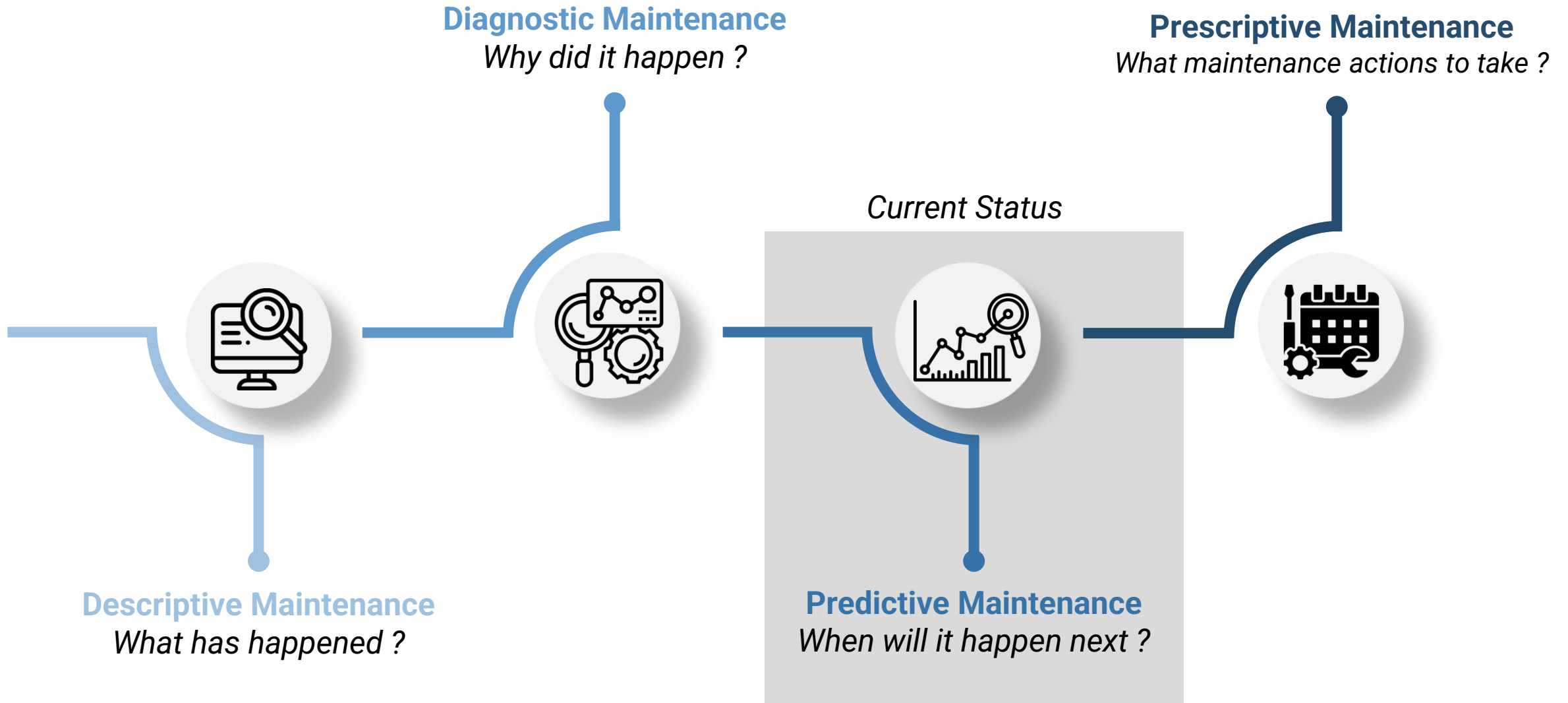


# METRIC DRIVEN FRAMEWORK FOR EVALUATION OF LOGISTICS IN PHM

**TANMAY DAGA**  
GERMAN AEROSPACE CENTER (DLR)  
INSTITUTE OF MAINTENANCE REPAIR AND OVERHAUL

# Evolution of Condition Based Maintenance Strategies



# Overview of PreMaDe



*PreMaDe is a tool intended to develop and evaluate **prescriptive maintenance strategies** for post-prognostics decision making.*

## Operator

Execute flights according to the planned schedule



Maintenance Downtime  
←  
→  
Curfew/  
Rotation Plan



## Maintenance

Perform necessary component repairs

Flight Schedule  
↓ ↑  
RUL



Spares Needed ↓  
↑ Inventory Status

## Degradation Model

RUL Prediction after flight ops



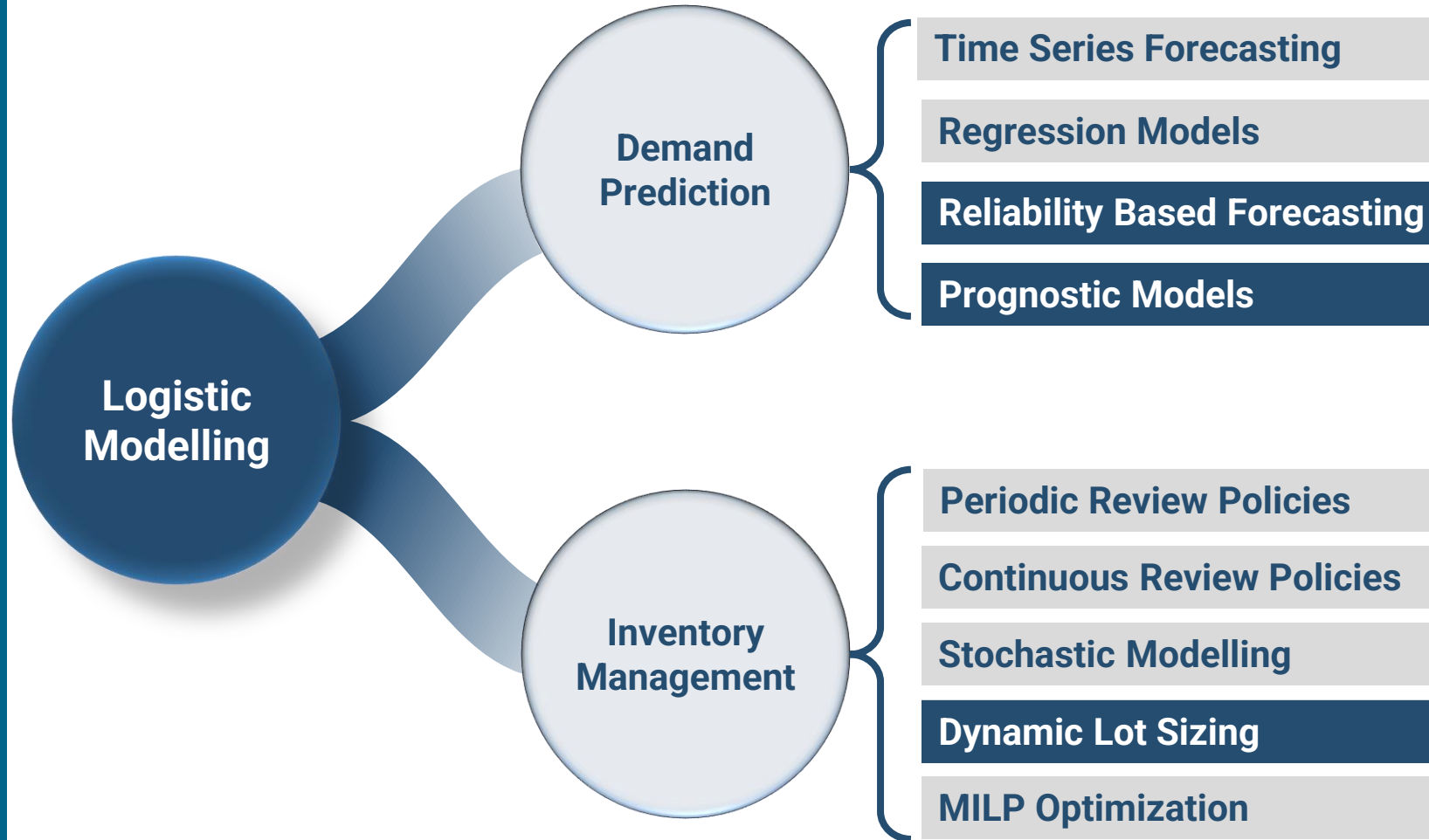
Part Condition  
←  
→  
Demand Forecast



## Logistics

Source necessary spare parts

# Logistics Modelling at a Glance



## Performance Metrics

### **Total Cost**

*Sum of all **ordering, holding and stockout costs** incurred during simulation period.*

### **Service Level**

*Measures the **ability to meet demand** without the occurrence **stockout**.*

# Key Challenges in Logistics for Prescriptive Maintenance



When does **prognostic information** improve inventory decisions compared to **reliability-based planning**?



How do **cost structures** influence optimal **ordering policies**?



Which **external shocks** have the **greatest impact on inventory planning** decisions?

A **rolling horizon methodology**, encapsulated within a **DES** framework is used for periodic simulation of **demand forecasting, inventory replenishment, component failures and replacement events**



## ***Condition Monitoring***

Determine the **age/condition** of the component



## ***Failure Prediction***

Use **reliability metrics** or **prognostic** to find the period which will witness the next failure

## **Reliability Metrics**

**Time to Failure = MTBF – Current Age**

A **rolling horizon methodology**, encapsulated within a **DES** framework is used for periodic simulation of **demand forecasting, inventory replenishment, component failures and replacement events**



## Condition Monitoring

Determine the **age/condition** of the component



## Failure Prediction

Use **reliability metrics** or **prognostic** to find the period which will witness the next failure

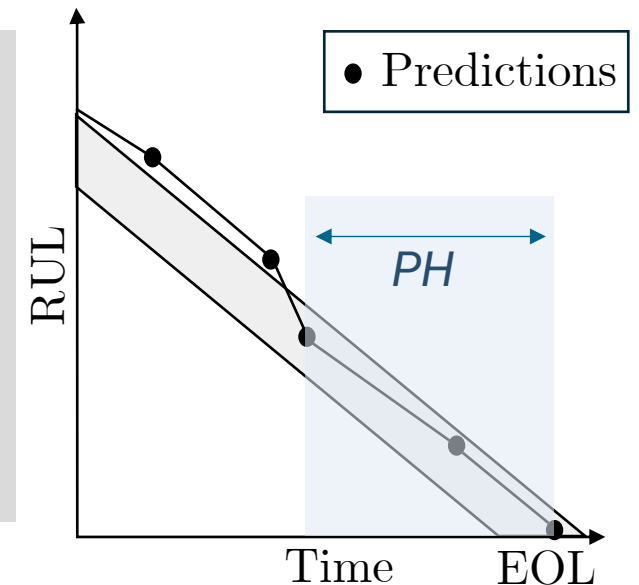
## Prognostics

### Prognostic Accuracy

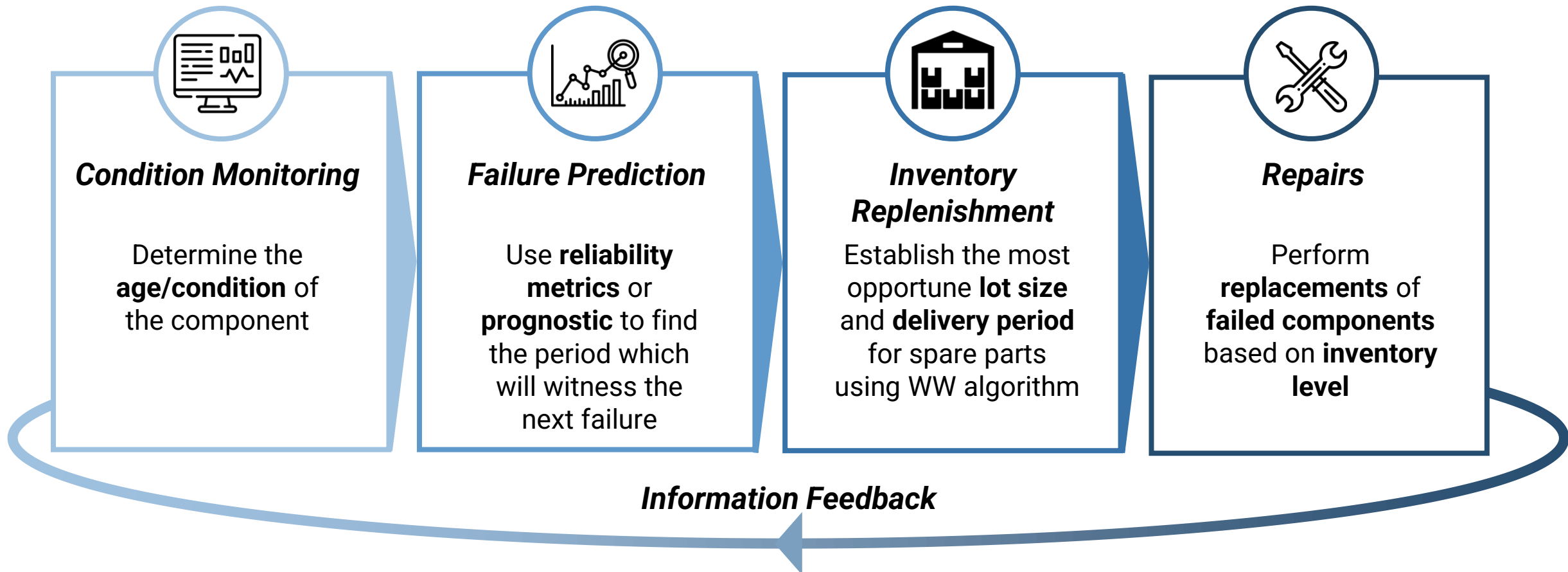
Acceptable Error Bounds

### Prognostic Horizon

Time before EOL, where the model confirms to error bounds

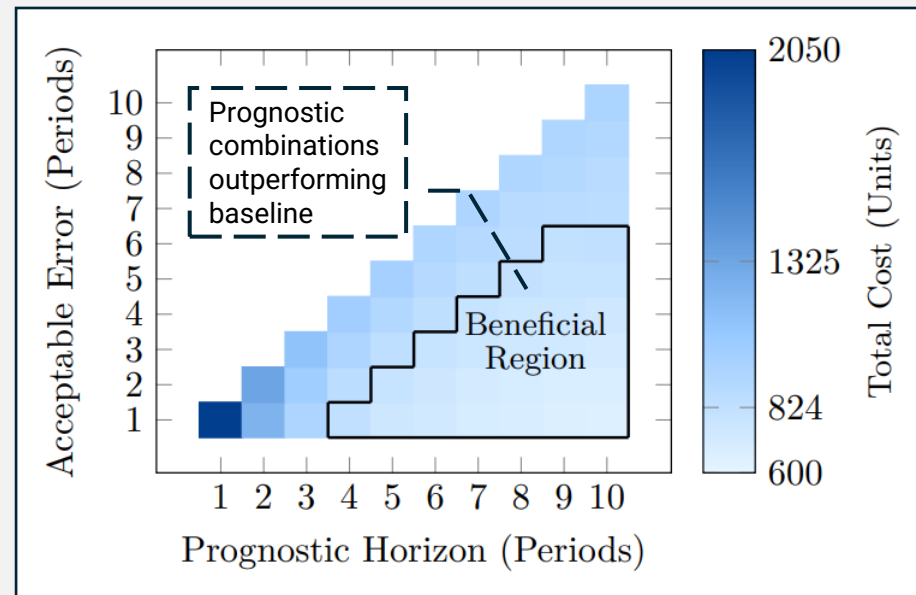


A **rolling horizon methodology**, encapsulated within a **DES** framework is used for periodic simulation of **demand forecasting, inventory replenishment, component failures and replacement events**



# Results: Effect on Total Cost

The **total cost comparison** between **statistics** (baseline – 824 units) and **prognostics** means of demand generation is represented in heatmap



## Impact of PH

Increment in PH is beneficial for total cost

- Earlier accommodation of demand in inventory planning
- Improved order consolidation to limit ordering

## Impact of PA

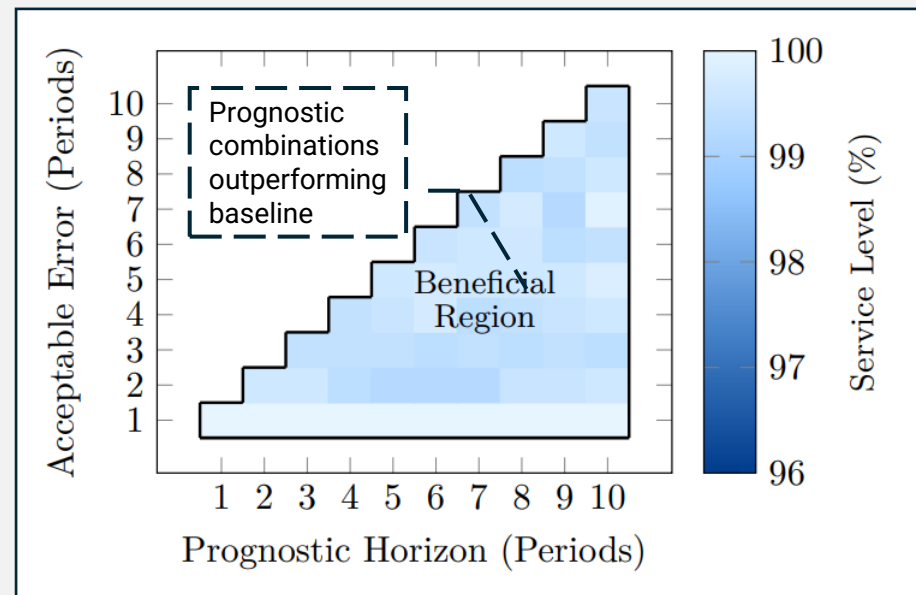
Total cost also improves with better prediction quality

- More accurate representation of demand
- Holding cost and stockout penalties less likely

Although enhanced prognostic capability contributes to cost reductions, the diminishing marginal gains over time call into question the economic justification for continued technological investment

# Results: Effect on Service Level

The **service level comparison** between **reliability (baseline – 96%)** and **prognostics** means of demand generation is represented in heatmap



## Impact of PH

**Increment in PH has no impact on Service Level**

- Since, WW assumes 0 lead time, delayed predictions do not affect the service level
- Sometimes, having lower PH is better to reduce faulty predictions

## Impact of PA

**PA improves service level, but the effect is very low**

- Early Predictions help service level → further facilitated by WW lot sizing

The improper or unstructured incorporation of external shocks, **such as lead time variability and false alarms**, can bias system behavior and lead to misleading or unreliable observations.

# Conclusion



- The proposed framework enables a **systematic comparison** of **prognostics-driven** and **reliability-based** inventory policies
- Prognostics-based strategies** outperform reliability approaches by leveraging **component specific, dynamic information relay** rather than **statical average values**
- Gains from improved **prediction accuracy** and **prognostic horizon** show **diminishing returns** beyond a critical threshold
- Inventory outcomes are highly sensitive to **uncertainty** and **external variability**, requiring **rigorous modeling** to avoid **biased conclusions**

# Thank You

## Questions ?



*Please feel free to connect on LinkedIn*

# Imprint



Topic: **Metric Driven Framework for Evaluation of Logistics in PHM**

Date: 2026-05-05

Authors: Tanmay Daga

Institute: Institute of Maintenance, Repair and Overhaul, Hamburg, Germany

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