Quantifying the Impact of Digitalization in a Power Generation Company

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Agenda

- Industrial Digitalization Background
- Research question
- Showcase introduction
- Methodology
- Results
- Conclusions and Recommendations

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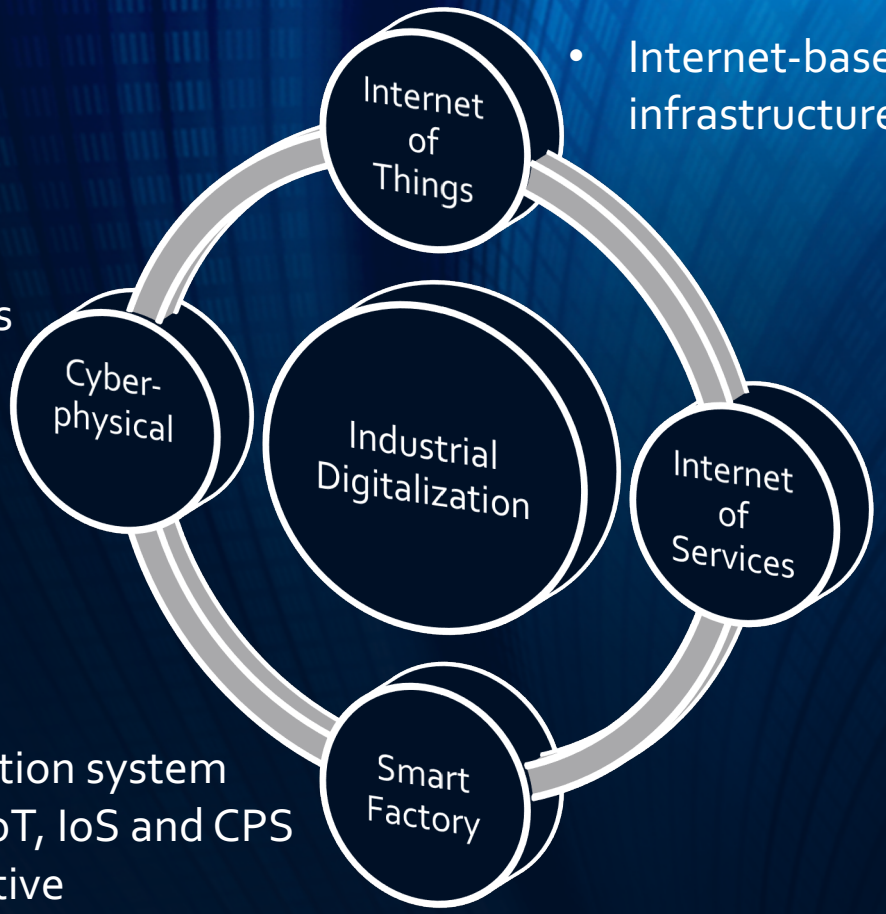
Industrial Digitalization Background

INDUSTRY 4.0 AND SMART MANUFACTURING



- Internet-based techical infrastructure

- Physical production flows connected with digital information flows
- Digital Thread

- Software as a Service
- Service-Oriented Infrastructure

- Decentral production system
- Combination of IoT, IoS and CPS
- 3D printing (Additive Manufacturing), robotics

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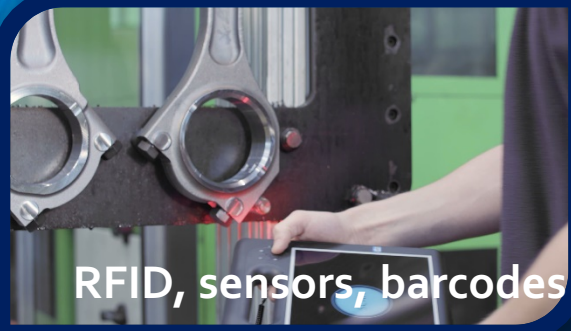
Smart Factory

- 3D Programming, Simulation and Printing

Paperless Manufactruring



RFID, sensors, barcodes

Robotics

Big Data

User Interface & Visualization

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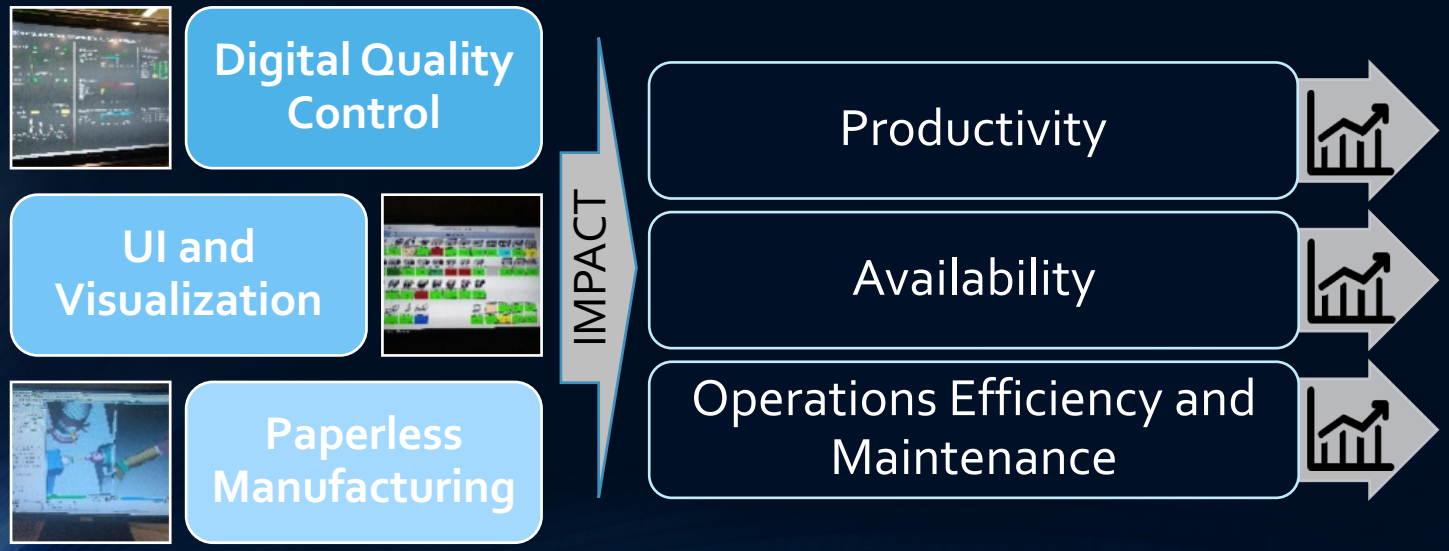
Research question

- Academia - many concepts proposed
- Studies based on interviews
- Assumptions: Digitalization boosts manufacturing supply chain performance
- Where is the quantitative proof?



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Showcase Introduction

SELECTED HYPOTHESES

Real-time graphical Information

CPS - SC Integration & Analysis (MES, ERP, CAD, Tableau)

UI & Visualization

Real-time Analysis

Continuous decision making

unplanned downtime ↓

early-stage planned maintenance ↑

machine utilization ↑

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Showcase Introduction

COMPANY AND DATA

- Test case: Impact of Visualization on manufacaturing SC performance
- Showcase Factory: Gas & Diesel Engines Manufacturer
- Data: historical records of various machine conditions in the Manufacturing Execution System (MES) since 2011
- Concept of visual interactive analysis – October 2016: touchscreen whiteboards, tablets, displays, Tableau

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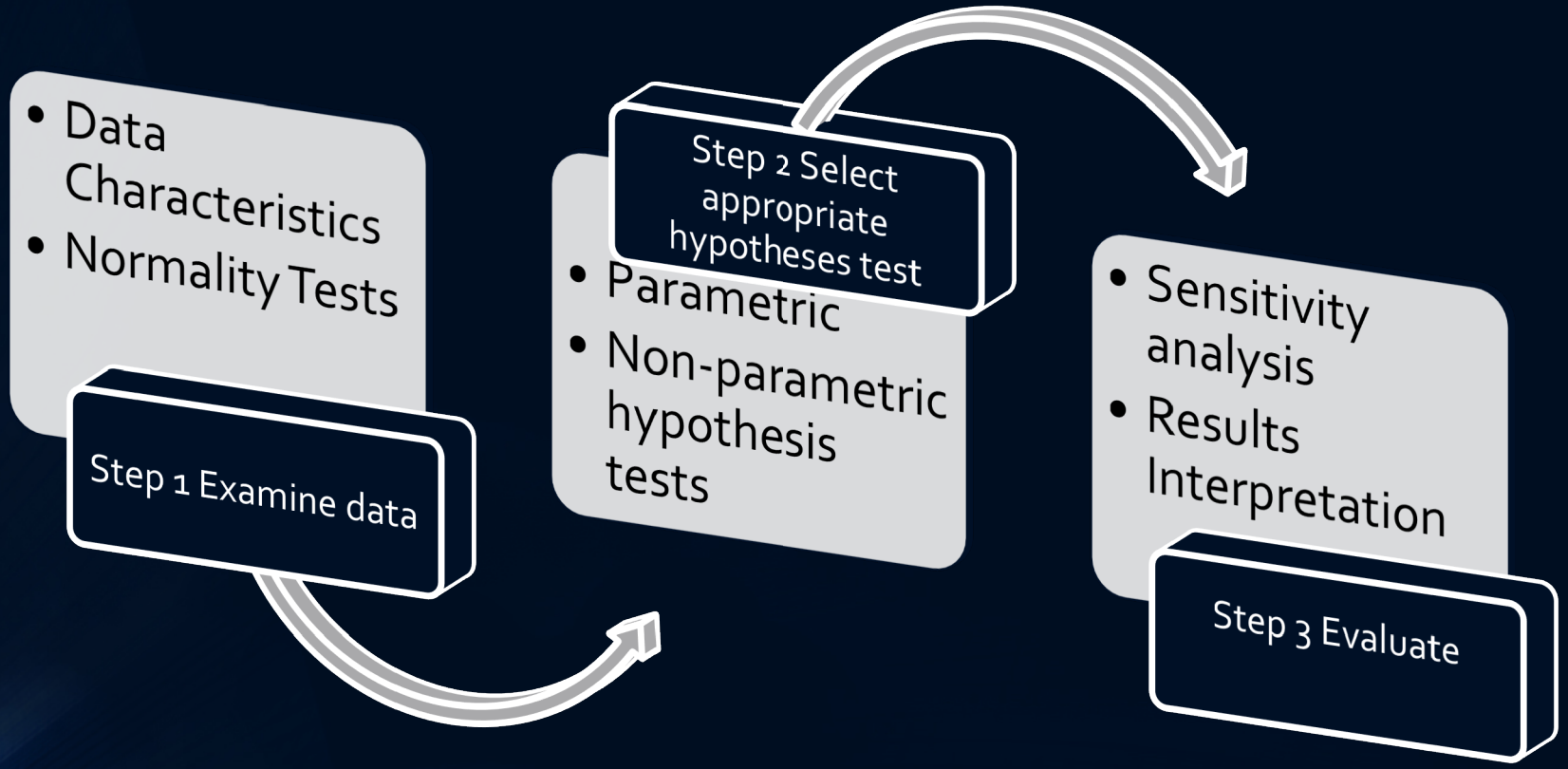
Methodology



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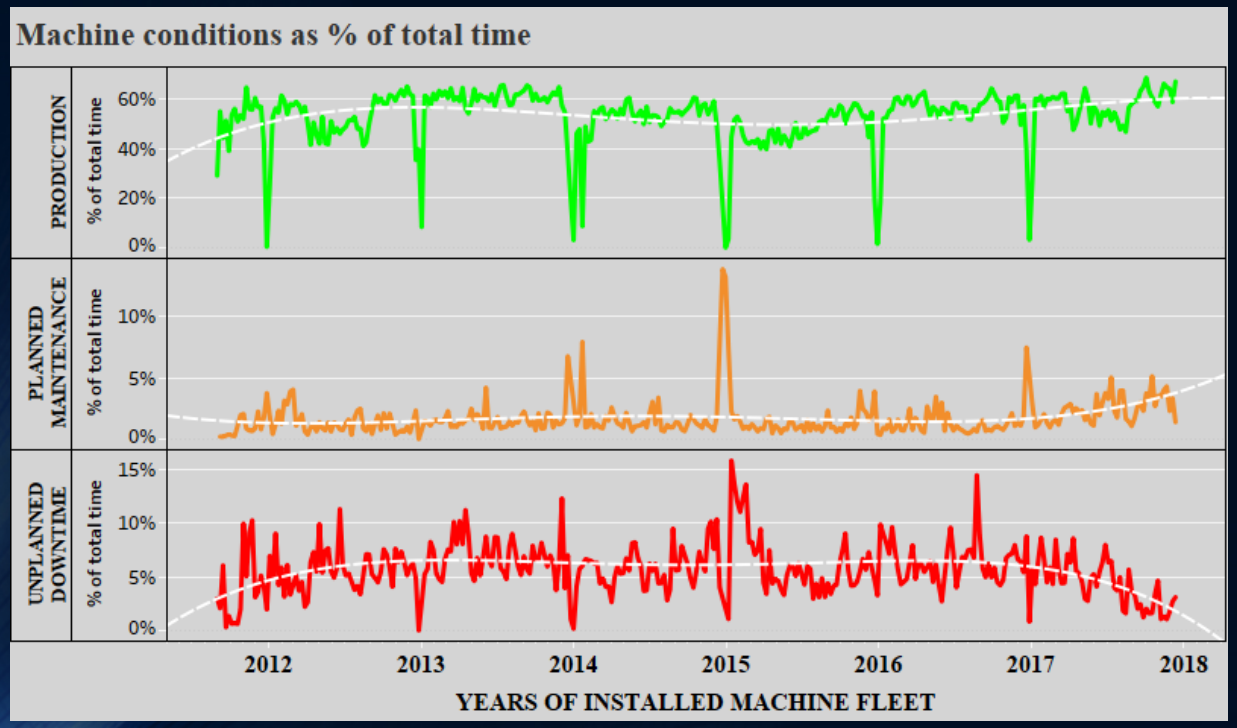
Step 1 - Examine data

DATA CHARACTERISTICS



- Data signals recorded instantly
- Data samples accumulated in one-week bins
- Units: Average duration of one condition in % of total
- Identification of outliers
- Examination of descriptive statistics

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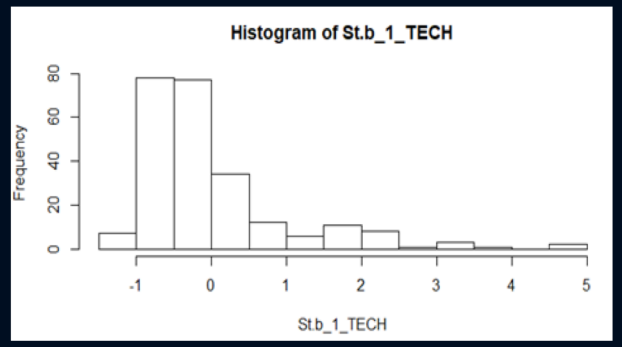
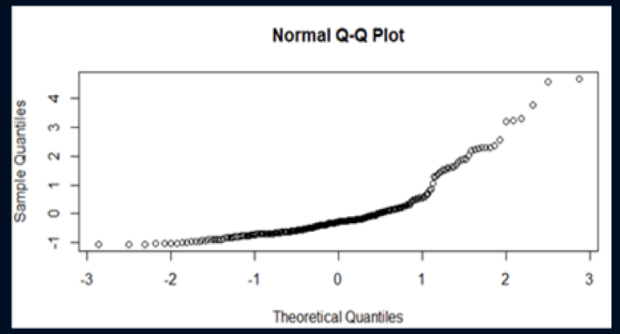
Step 1 - Examine data

NORMALITY TESTS

- Graphical





- Numerical (-2 < β < 2)

	Kurtosis			Skewness		
	Planned Maintenance	Unplanned Downtime	Machine Utilization	Planned Maintenance	Unplanned Downtime	Machine Utilization
Machine cluster 1	7.56196	4.70336	1.09605	7.59543	2.05665	-0.5024

- Formal: Shapiro-Wilk test: W = 0.69465, p-value = 1.99e-10

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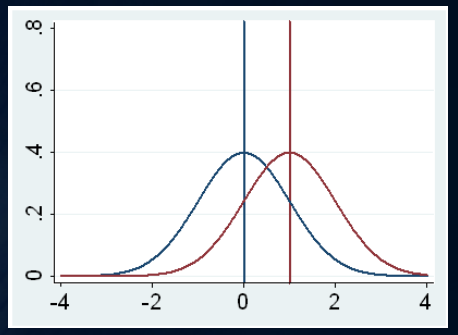
Step 2 - Select appropriate hypotheses test

PARAMETRIC INFERENTIAL STATISTICS

- t- test for two dependent samples



NON- PARAMETRIC INFERENTIAL STATISTICS

- Wilcoxon Signed-Ranks Test
  - More than two subjects = 13 machine clusters
  - Sample pairs are dependent = data before and after is compared for the same machine cluster

Wilcoxon Signed-Ranks Test

78 samples: 13 machine clusters * 3 machine conditions * 2 before/after pairs

1. Calculate differences between sample means
2. Take absolute values and assign ranks: highest rank for the largest difference
3. Assign the polarity to the ranks
4. Create 2^n permutations of all possible combinations of signed ranks
5. Examine which rank is assigned to the observed value
6. Calculate the sum of positive and negative ranks and p-value
7. Can be conducted in R

	Mean of pre-implementation data X1	Mean of post-implementation Data X2	Difference D	abs. |D|	Ranks R of |D|	Signed ranks R+/R-
Machine cluster 1	4	1	3	3	2	2
Machine cluster 2	6	8	-2	2	1	-1
Machine cluster 3	9	2	7	7	3	3

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Step 3 – Evaluate Results

MACHINE UTILIZATION

- H_1: Visualization increased machine utilization
  H_1: $X_1 < X_2$
- H_0: $X_1 \geq X_2$
- V = $\sum R_+$ = 16 and p-value = 0.0199
- H_0: rejected with 95% confidence

PLANNED MAINTENANCE

- H_1: Visualization increased planned maintenance
  H_1: $X_1 < X_2$
- H_0: $X_1 \geq X_2$
- V = $\sum R_+$ = 7 and p-value = 0.002319
- H_0:rejected with 99% confidence

UNPLANNED DOWNTIME

- H_1: Visualization reduced unplanned machine downtime
  H_1: $X_1 > X_2$
- H_0: $X_1 \leq X_2$
- V = $\sum R_+$ = 57 and p-value = 0.2274
- H_0 not rejected

Step 3 – Evaluate Results

SENSITIVITY ANALYSIS

- Test run without a machine cluster with atypical record pattern
  → The p-value of unplanned downtime closer to significance level: p-value ≈ 0.07

- Other variations: shorter period of observation, tests without clustering, exclusion of single machines with atypical pattern
  → The results of the test remain robust

VISUALIZATION IN INDUSTRIAL POWER EQUIPMENT MANUFACTURING

MACHINE UTILIZATION AND PLANNED (PREVENTIVE) MAINTENANCE

✓ Significant

UNPLANNED DOWNTIME

✗ Not significant

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Conclusions and Recommendations

MICRO PERSPECTIVE

- Implementation of UI & Visualization partially sucessful
- Simple methodology universally applicable

MACRO PERSPECTIVE

- More academic focus on manufacturing SC needed
- Digital mind-set in power industry still in early growth stage

Recommendation: Bridge between academic research and industry
→ Co-development of pre-concepts and post-quantitative analysis

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THANK YOU! | QUESTIONS?

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