Toward a Zero-Defect Manufacturing: Development of a Holistic Quality Management Platform

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WHIRLPOOL CORPORATION

World’s leading major home appliance company (NYSE: WHR)

Approximately $20 billion in sales in 2019

77,000 employees

$1 billion investment in capital and R&D centers annually

67 million products sold in more than 170 countries in the world

59 manufacturing and R&D centers

A LEADERSHIP POSITION
EMEA

INDUSTRIAL FOOTPRINT

Melano
Italy

Comunanza
Italy

Cassinetta
Italy

Siena
Italy

Carinaro
Italy

Naples
Italy

Yate
UK

Wroclaw
Poland

Łódź
Poland

Radomsko
Poland

Poprad
Slovakia

Lipetsk
Russia

Manisa
Turkey
## QU4LITY in a Nutshell

<table>
<thead>
<tr>
<th><strong>Project No:</strong></th>
<th>825030</th>
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<tbody>
<tr>
<td><strong>Project Full Name:</strong></td>
<td>Autonomous Quality Platform for Cognitive Zero-defect ManUfacturing 4.0 Processes through Digital ContInuity in the Connected FactorY of the Future (QU4LITY)</td>
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<td><strong>Duration:</strong></td>
<td>39 months</td>
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<td><strong>Start date:</strong></td>
<td>January 1(^{st}) 2019</td>
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<td><strong>Partnership:</strong></td>
<td>45 partners, 13 countries</td>
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<td><strong>Strategic Objective:</strong></td>
<td>DT-ICT-07 (Digital Manufacturing Platforms for Connected Smart Factories)</td>
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<td><strong>Total Eligible Cost:</strong></td>
<td>19,520,535.28 EURO</td>
</tr>
<tr>
<td><strong>EC Contribution:</strong></td>
<td>15,998,180.54 EURO</td>
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QU4LITY in a Nutshell

AUTONOMOUS QUALITY (AQ) PLATFORMS FOR COGNITIVE ZDM VIA DIGITAL CONTINUITY IN THE CONNECTED FACTORY OF THE FUTURE

ECOSYSTEM
45 champion partners mobilised
- Manufacturers
- Platform Owners
- Digital Technologys providers
- Innovators
- 8 digital Innovation Hubs involved

TECHNOLOGIES
65+ Digital Technologies used
- AI, Distributed Control, Big Data, Blockchain
- CyberSec, Edge, SDN, Plug & Control
- 15+ Digitally-enhanced cognitive platforms

PILOTS
14 lighthouse pilots on 7 sectors
- 9 production factories’ pilots on processes
- 5 plug & control manufacturing equipment pilots

STANDARDS
10 standards' contributions
- Alignment of standards: IEC Adminsitration Shell, Automation ML, IEC Smart Factory Architecture & IEC cybersec, NIST Vocabularies (IOF, QIF, ...), W3C WoT, ETSI Context Broker, MIMOSA, etc.

OPEN-CALLS
1 Million Euro for third-parties
- Competitive calls directed at SMEs
- Between 11-16 additional sub-projects

INNOVATION
1st Europe-wide DIH for ZDM
- Market Platform for AQ ZDM Solutions
- Certification4.0 against standards

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Business Motivation: As Is

**Heat pump**
- Functional test heat pump

**Assembly Line**
- Advanced Testing:
  - Connection to test equipment
  - Quality Data Collection
  - Quality Gate
  - Visual check & repair
  - Zero-hour test
- Data visibility & Analytics:
  - Track&Trace (Serial/Tracking)
  - KPIs
  - Calendar Management
  - People Tracking
  - OEE Monitoring
- Automated Material Handling:
  - Shopping lists

**Drum line**
- Drum line

**MES Standardization**
- Production Plan Management
- Routing Management
- BOM Management
- Work instructions (SOP/OPL/kitting/touch up)
- Control Board Programming
- Begin of line
- Hold Management
- Improved Print & Apply

**Finished Goods Area**
- Heat pump Assembly Line
- Finished Goods Area

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Business Motivation – Problem Addressed

- Quality data are currently managed as islands and with low correlation between the many data generated at each Quality gate.
  - Lack of standard methods and tool to gather, store and share data
  - Lack of flexible and user friendly analytical tools
  - Lack of a comprehensive way to share results or data analysis and link them to business priorities
  - Lack of a common and a holistic semantic model able to represent concepts at different stages of product lifecycle

The full potential of data generated is not exploited yet and any attempt of using the data are currently requiring a strong specialization and specific knowledge plus a time-consuming effort to query database and manually correlate and analyze data.
To-Be scenario

- **Analytics Quality Trend Cockpit**
- **Cpk and Kpi Trend Cockpit**
- **QU4LITY Repository**
- **Mfg Data Ontology Normalization & MPFQ Modelling**

**Analytics Quality Forecast**
- Quality Analytics Correlation
  - Noise
  - Energy
  - Dryer Performance
  - Components
  - Performance

**Materials**
- Functions
- Processes

- **Drum Line**
- **Vacuum and Charge**
- **Heat Pump Test**
- **Assembly**
- **Functional Test**
- **Aesthetical Check**
- **Final Electrical Test**
- **Quality Gate**
- **Repairing Area**
- **ZHQC**
- **Repairing Gate**

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Why normalize data in factory?

- Manufacturing is the only point of integration between the concepts and the reality
- Manufacturing is the only point in which the Customer Domain is brought into reality and satisfied (or dissatisfied)
- Future Manufacturing concept need to better integrate these two distinct processes
Product Development identifies critical characteristics of components and tolerances.

So far we measure things different to what we are selling to our customer.

Quality Features valued by the user:
- Noise Reduction
- Energy Class
- Power Consumption
- Drying Performance
- Durability
- ...

Material attributes:
- Power
- Rpm
- Water Quantity
- Temperature
- ...

Mfg Processes

Appliance Function Analysis

MPFQ MODEL

Holistic Semantic Model
The MPFQ Model is the integration in term of data and methodology of four different entities:

Material – Process – Functions - Quality

Material:
- Technical Characteristics
- Measure Data Collection

Process:
- Pk
- Cx
- Cy
- Cz
- Cn
- Technical Characteristics
- Measure Data Collection
- Default Parameters Setup
- Process Sequence

Function:
- Fj
- Cx
- Cy
- Technical Characteristics
- Measure Data Collection
- Performance Indicator
- Technical Characteristics

Quality:
- Qj
- Perceived Quality
- Performance
- Durability
- Reliability

Holistic Semantic Model
First step: start from Bill of Material and decompose it in main modules

- Control Panel
- Door and Font Panel
- Drum and Cabinet
- Motor and Heat Pump
Second step: identify relations between components
Third step: Build the functional model

- **Quality indicator**
- **Component/Material**
- **Function**
- **External element**
Fourth step: associate a process for each component-function

- Pick and Place
  - Base assembly
  - Hold
- Evaporator
  - Cool
  - Capillary
- Welding
  - Leakage
- Noise
  - Silent block
  - Hold
- Energy consumption
  - Compressor
  - Push/Heat
  - Vacuum and Charge
  - Refrigerant
Fifth step: associate a weighted consumer Q to component-function

QA_n = Product Quality Attribute n
VQA_n, MPFm = Variable that indicates the influence of MPFm on QA_n
Weight P1 = Weight process 1 vs single QA_n
Weight C1 = Weight component 1 vs single QA_n
Weight F1 = Weight function 1 vs single QA_n
Sixth step: build Data Ontology Model
Pilot QU4LITY Architecture & QU4LITY Technologies
The analytics tool processes the data made available from the QU4LITY Cloud Bridge.

MPFQ indexes are extracted.

The MPFQ model is used to estimate quality.

Results from the MPFQ model are sent back to the QU4LITY Cloud Bridge.

The loop is closed thanks to the QU4LITY Trend Cockpit and the Decision Support System.
Human and Machine decision on product and processes will be augmented by the capability of autonomous system to actually correlate **consumer needs** and **perceived Quality** with production parameters and thus **improve the speed of decisions** and their **effectiveness**. This will impact both the Quality related metrics, **reducing defective products on the market**, and the Productivity, metrics letting operator spend **less time in expensive analysis** and moving as much as possible **decision steps from them to machines**.
Visit us at https://qu4lity-project.eu/

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