**TagItSmart**

**Smart tags driven service platform for enabling ecosystems of connected objects**

**Grant agreement 688061**

# Qualytics

# D3.2 Final report

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# Executive Summary

This document provides a final report about the work done in Qualytics.

Main objectives of the document are:

1) To explain what has been achieved and how it can be reused for the further business development
    - what is the new service
2) To analyse some of TiS technologies in the context of proposed service
    - which improvement in TiS technologies would improve the new service
3) To elaborate on the impact of Qualytics
    - why the project is a success

The document summarizes the most important experience from the entire work, starting from the conceptualization, till the development and the validation of the system. The aim of the document is to clarify some of the issues which were challenging for each of the phases.

Additionally, this document reports about the importance of Qualytics for the development of our expertise in the Digital Twin domain.

# 1. Introduction

## 1.1 Scope of the deliverable

This deliverable is part of the WP3 (Promotion and Feedback), which main objectives are to:

- ensure an efficient dissemination of results
- provide timely ad valuable feedback to TagItSmart!.

In particular, the work is related to the task T3.2.

## 1.2 Contributions to other WPs and deliverables

This deliverable is based on the work done in WP1 and WP2

## 1.3 Structure of the deliverable

This document is organized in the following way:

In the second section we provide the description of the new service

In the third section we provide a summary of the developed business case

In the fourth section we analyse the advantages of using QR code technology

In the fifth section we elaborate on the achieved impact

In the sixth section we provide some concluding remarks.

## 2. New Service in the nutshell

In this section we provide a short description of the provided service that should be used for getting attention of potential customers/partners.

**Name of the service**:

***Improving quality control by managing temperature fluctuation patterns based on smart tags***

**Motivation/Problem:**

The goal is to define the procedure for checking the quality of the maintenance service performed on the cooling part of a refrigerator.

The problem is an unstable behaviour of the cooling part after reparation which is reflected on the fluctuation of the temperature in the fridge, usually happening in the first days after reparation.

The fluctuations are also observed in the functional tests performed after assembling process, so that the knowledge about the shape and duration of some fluctuation are known. Since there are different types of the fluctuation we will focus on those which range corresponds to the characteristics of the smarttags we will be receiving (thinfilm).

**As Is – current problem in the industry**

The existing procedure doesn't enable remote checking of the fluctuations in the temperature

**To Be - Requirements**

The solution should be easy to install / de-install and if possible to be reused.

It should be installed by the non-experts

It should serve as the quality check for the maintenance process

**Solution**

We have designed the system which combines IoT and Data Analytics for Quality Control

The main goal is to integrate:

- Information about the behaviour of a model (data analytics from functional tests)

  - Requested for the definition of the range in the fluctuation of the temperature (data analytics)
- Measurements after service/repair based on the customer complaint
  - Checking the validity of the fluctuation in the temperature (tagging technology)
  - Customer is reporting the measurements outcome

The checking procedure (tagging) can be complicated (depending on the smarttags) but we work on the basic case for PoC

**Architecture of the system**

The system consists of two main parts:

1) Edge processing that is responsible for detecting simple or complex situations (collecting local context)
2) Server processing that is related to the integration of information collected from edge and processing in the global context

**Possible extension**

This scenario can be connected to the information about the customer complaints

**Advantages**

The main advantage is the possibility to check some hidden variations/fluctuations in the temperature, which can indicate some anomalies in the operation of a device. This has two positive implications:

1) Some important information related to the temperature fluctuations can be captured (using low cost technologies). For example, it is possible to define a very precise temperature range that should be observed

2) The customer can be more actively involved in the maintenance process

We argue that such an approach can change the way how the maintenance process can be organized in order to enable much faster discovery of problems.

This approach is the first step in developing a larger edge event collection system that is able to easily detect specific events that might influence the usual/proper operation of the system.

**Ways of collaboration**

In the following figure we illustrate an approach for collaborating with potential users/customers.

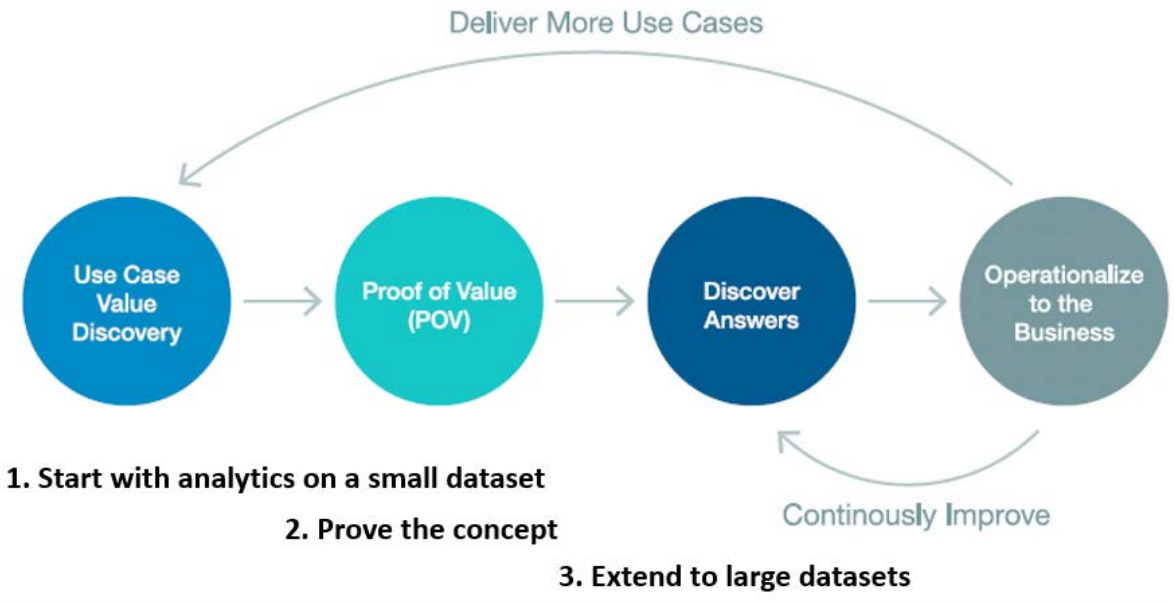


**Figure 1**: Service application process in industry: From a test to the operationalization

**Use Case Value discovery**

- This is the first and most important step in the process
- It usually starts with a workshop on site:
  - two hours introduction in industry data analytics
    - clarifies why the analytics is important
    - explains our approach
    - Participants: senior managers from the domains that data analytics can be relevant for (e.g. asset management, quality management)
  - half-day workshop
    - structured brainstorming about use cases
    - Goal: to identify potential use cases
    - Participants: operational managers, domain experts (from relevant domains)

# 3. Business case explanation

In this section we provide details of the implemented business scenario.

## 3.1 Business System

Industry use case was performed for Whirlpool in the domain of the ZHQ (Zero Hour Quality), a quality management approach that aims in having a valid product (high quality) from the beginning of the usage (zero hour) of a product/device. In order to achieve this, there is a very strict process of functional testing after assembling process that consists of 10+ measurement stations where different parameters of the operation of the assembled devices are checked.

### 3.1.1 New quality control approach

The quality control process is done using a traditional threshold-based process, producing so called out-of-limits (OOL) alarms. It consists of defining an upper and lower threshold so that when a measurement goes above the upper limit or below the lower one, an alarm is triggered. Thereafter engineers will inspect the parameter that is out of limits and determine whether it is an anomaly or not and decide which action to take (for example, run a procedure).

The main issue is that the thresholds are defined by experts and might be suboptimal, i.e. they could be refined, but the data for the refinement is missing.

We briefly list the most important elements from the Whirlpool use case:

- For each refrigerator that Whirlpool produces, a functional test is performed by attaching sensors and measuring a number of parameters;
- Functional tests validate that a refrigerator works as it should and represent one of basic measures of quality control;
- For the dataset provided following 6 (behavioural) parameters are measured (see Figure 1 for an example):
  - Temp. Destra (Rossa), Temp. Sinistra (Nera), T EV Cap Fz., T EV Cap. Fr., Cos Fi, Potenza;
- There is a need to include contextual parameters into analysis as well. Following contextual parameters can be provided:
  - Time when the functional test was performed;
  - Temperature of the environment in which functional test was performed;
  - Location (part of the factory) where the functional test was performed;

- The dataset is too large to be processed on a single machine and that is why we need a scalable, distributed solution which is able to bear with Big data;
- The feedback from customers, (esp. through maintenance process) is missing;
- The dataset should be extended with the customer-driven information.

In the following figure the real architecture that integrates quality control approach, as described above, is shown. The most important part is Q-Box, which implements a simple detector and can be easily moved from one to another place.

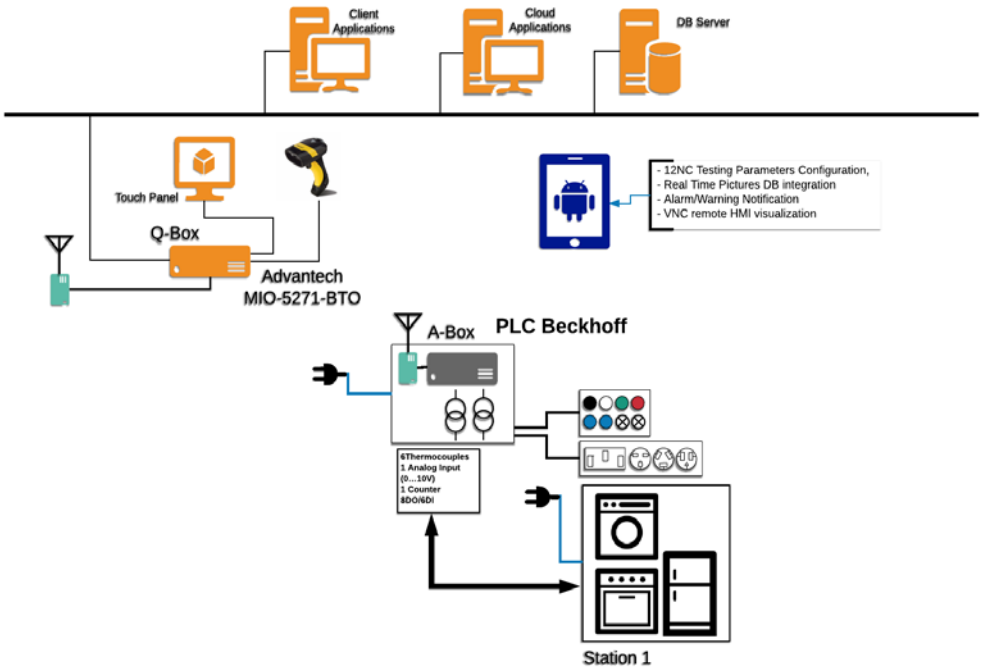


**Figure 2:** Improved quality control process using portable measurement device (Q-Box)

## 3.2 General scenarios and advantages

We argue that there are many business scenarios that can be supported by the presented approach (in the case that also other techniques for the smarttaging can be used).

We mention here two innovative applications in maintenance service, which can be developed if the business case developed as planned:

1. To record that a device behaved (at home) in an anomalous way
    - Smarttags values (like QR code colours) indicate the existence of the anomalous temperatures;

- This data is used for matching with the functional tests of that device in order to create a basis for analytics;

2. To check how a device will behave
    - To check the behaviour of the device, which has been repaired (maintenance service done on demand);
    - Such a device is equipped with several sensors/tags (like Thinfilm), which record the behaviour of the device in a limited time period (1-2 days);
    - The data from tags are analysed in order to check if some anomalous behaviour;
    - An approach similar to the „holter“ for patient monitoring (eHealth).

The main advantages are:

- A very efficient way for improving:
    - Maintenance service
        - Better diagnostics (more data to be used)
        - Personal with less experience can perform the tasks
    - Functional test process
        - Data from the anomalies at home-usage will be used in the data analytics to find causes of some potential problems in the usage of devices
    - „Self-alarming“ service
        - A customer can check on his/her own if the device behaved anomalously (related to the values for the temperature)

In order to illustrate some potential new services, in the following subsection we explain a scenario for condition-based maintenance of home appliances

## 3.3 New services for home appliance products which are retrofitted using smart tagging

The main goal of the Qualytics approach in this scenario is to improve several aspects of a retailer’s services through the introduction of the complex processing of the integrated product-related data including the data received from smart tags.

The main objective is to enable retrofitting of the products through the usage of smart tagging technology to make them more service-oriented, i.e. to create different added value services, like a more efficient maintenance process

The main idea/ motivation is to break the silos between manufacturer (or someone responsible for the quality control of the product), retailer and maintenance-servicer in order to:

- Ensure that the maintenance of a product will be done in the most efficient way
    - Design and offer *condition-based maintenance* as a novel way to maintain home appliances, enabling predictions when a concrete product should be maintained based on the analysis of the data about the usage of the product (as a difference to planned maintenance defined for a class of products). This way of maintenance considers the real usage of a product and all specifies of that usage (personalized maintenance).
      IMPORTANT: Several additional services can be defined based on the collected data, incl. building the profiles of the customer behaviour (valuable for offering new products, or new models of the same product type). This can include also the analysis of the energy consumption (by the user)
- Improve the knowledge/experience (of retailer) about the REAL quality (as perceived by a user) of some products through in-use testing/monitoring of the product and its correlation with the quality control data. This will enable a retailer to:
    - Provide suggestions for the product improvement
    - Test the performances of the particular vendors/manufacturers
- Engage the users in the maintenance process
    - Enabled by in-use monitoring of the quality characteristics

- Improve the quality control procedures by collecting the data from in-usage maintenance and compare with the quality controls data

The scenario will serve as the proof of concept (PoC) for the new services, esp. from the point of view what is the quality and quantity of data that can be received from smart tags. From this reason, this PoC doesn't require a huge amount of data to be collected from different data sources (e.g. from the quality inspection process), but rather the availability of the representative samples which will be used for the design and in the test phase

Main stakeholders in the scenario:

- If available, Manufacturer, who guarantees the quality of the product. If the manufacturer is not available, quality control data can be obtained
- Retailer ensures the full customer support and increase customer loyality
- Maintenance professionals increase customer satisfaction (and offers new services)

Prerequisites:

- Retailer sells a product and has all catalogue data related to maintenance of that product (e.g. when the maintenance should be done)

- There is data from the tests performed on that product
- Maintenance service installs smart tags
- Customer uses the product regularly and checks smart tags periodically

Impact: retrofitting products to enable their (remote) monitoring and control

Constraints: types of smarttags that can be used for in-use montoring

We argue that the usage of different smartags (e.g. QR codes) would enable even more additional scenarios. The main advantage is the possibility to model more complex situations of interest.

In the next section we explain the possible advantages of using QR code in the context of support complex event processing (CEP), which is one of the most important technologies for edge processing (as a part of the Digital Twin development)

# 4. Smart tags: QR code for complex event processing

## 4.1 QR code tagging process for CEP

We started the work by assuming that QR codes will be available. We found that smart tag especially relevant for the complex event detection on the edge. However, the technology was not ready to be used for our tests.

We provide here the analysis of the principles how the required, quality-control related measurements can be realized using QR code.

This is the most interesting usage of the TagItSmart technologies, elaborated and discussed with different project partners. It enables the representation of complex situations (usually defined as complex event patterns). In the following figures we present our approach that is based on the usage of QR code.

Figure 3 illustrates one complex event, which is relevant for the selected use case.

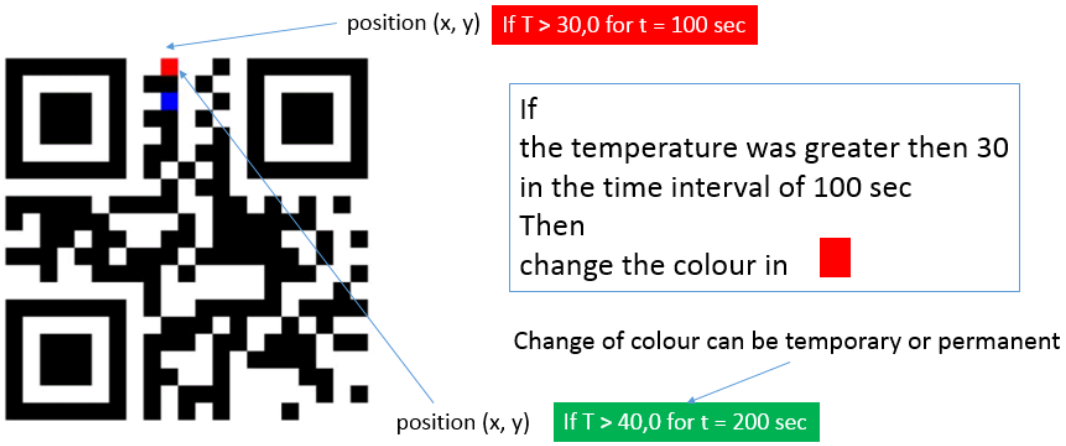


Figure 3: Representing complex events: one pixel codes one event

Figures 3 illustrates a sequence of complex events that builds a complex situation. This is the most critical part in representing complex situations: how to combine complex events in meaningful situations.

Figure 4 illustrates a so called normal behaviour in the changes of the temperature. The goal is to enable the detection of such complex situations based on changes in QR code. We have developed a method for coding a complex situation in a sequence of complex events that can be coded in a single pixel.

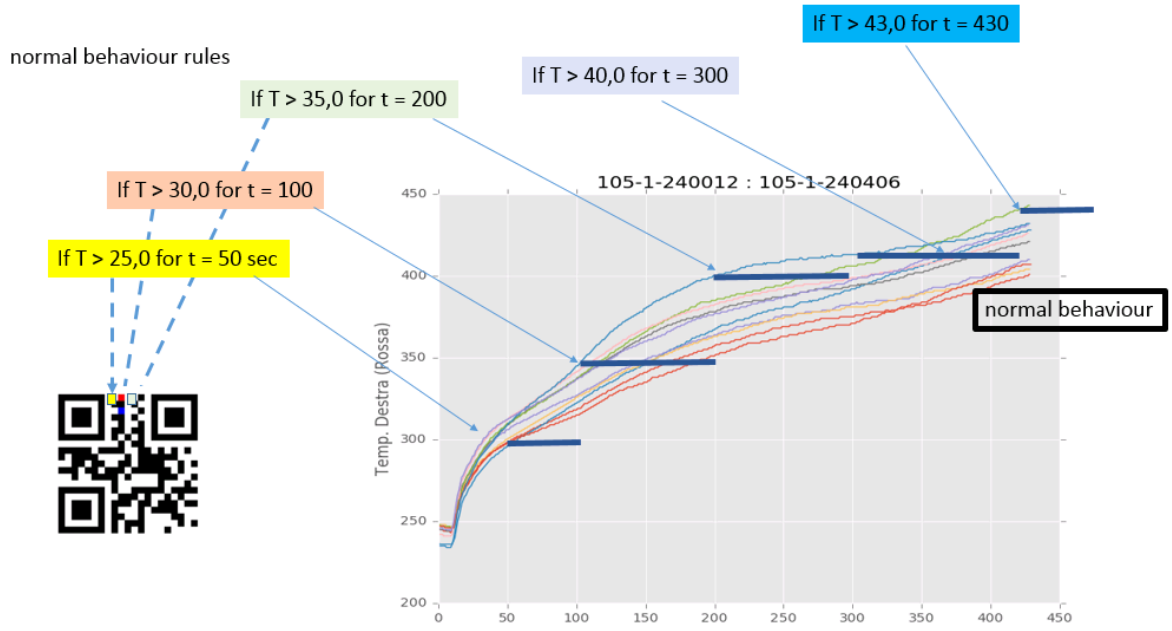


Figure 4: Monitoring specific changes in the temperature

Figure 5 describes a requirement for QR code technology: several rules should be mapped in one pixel. This will make the coding of rules more compact.

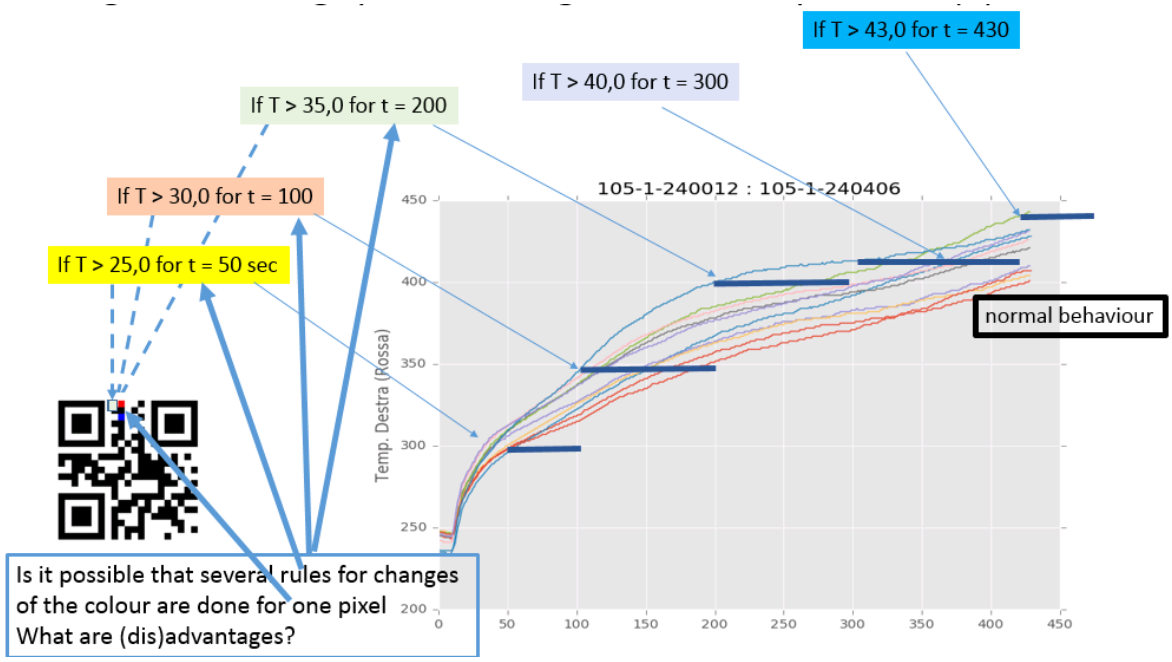


Figure 5: Monitoring specific changes in the temperature

Figure 6 illustrates the detection of an anomalous behaviour (complex situation). In this case the increase of the temperature is too fast comparing to the normal behaviour. As illustrated in figure, one of the requirements is to send notifications about the detection of a complex event as soon as it arises.

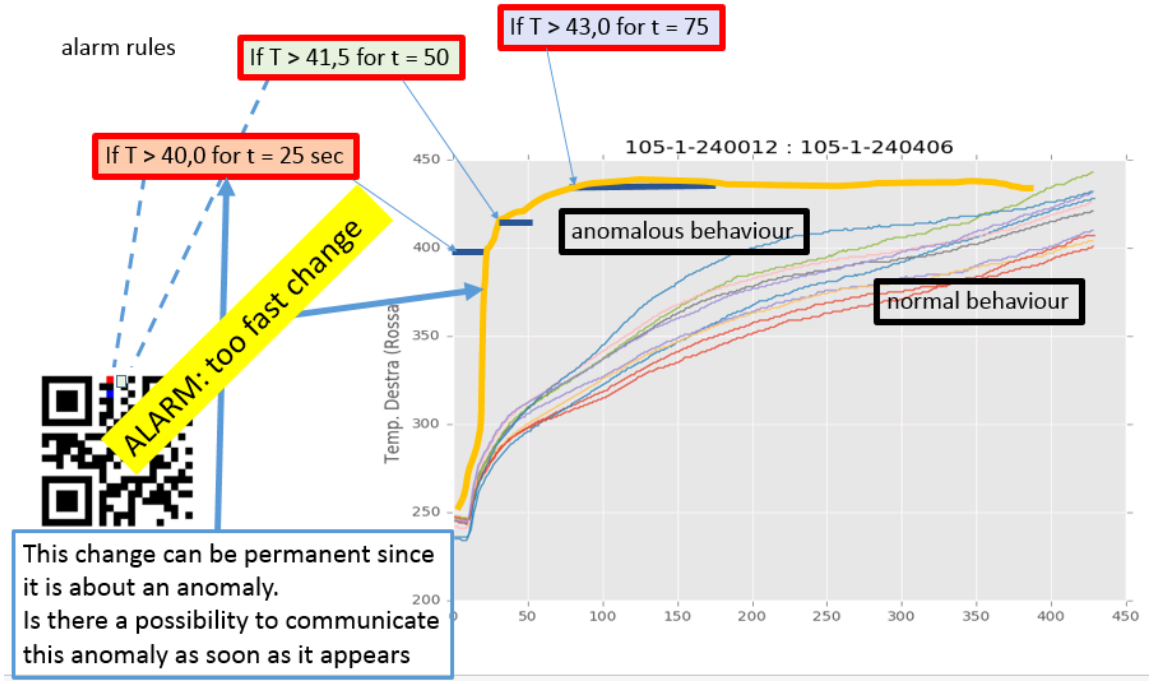


Figure 6: Detecting anomalous changes/behaviour

## 4.2 Temperature measurement analytics using QR code

In this subsection we provide an approach for mapping sensor values into event for complex event processing.

QR code sensor changes value based on temperature change over time. In order to have full history of temperature change over time following detection is necessary:

- Duration of measurement will be split in N equal parts. (If we measure temperature for 3h and we want temp change on every 15 mins we would need 12 parts).
- For every part we would need M “codes” based on temp range we want to measure. (For example we could have one code for if temp is above 200, another one for over 250 etc.)
- QR code sensor should be set up to measure temp from “0 time” to first part, from “0 time” to second part etc. For every part measurement there are M temp ranges.

After temperature is measured we will have temp ranges during measurement period, which can be represented in table below.

| Temp\Time | 15min | 30min | 45min | 60min | 75min |
|---|---|---|---|---|---|
| 350 | | | | | |
| 300 | | | | x | |
| 250 | | x | x | x | x |
| 200 | X | x | x | x | x |

X represents that temp value has been reached. From the following reading we can approximate function of temp change over time, which then can be used in analytics for anomaly detection.

# 5. Impact

The proposal has realized four types of the impact we describe in the following subsections.

## 5.1 Increase competitiveness

Nissatech is provider of big data solutions and active in the manufacturing domain, where the need for processing huge amounts of (dynamic) data is emerging. Qualitics is a novel approach in the intersection between smart tagging, quality control and data analytics. This proposal provided an important contribution to the competitive advantage to the company by a) demonstrating that such an approach can be realized (proof of the concept) and b) creating experience about the challenges in providing such a service (risk-reach activity).

This experience is formalized in a business model that is one of the results from this proposal. It has enabled the design and implementation of the market-ready service that will be successfully offered worldwide.

The business model for our data analytics services usually follow SaaS (Software as a Service) revenue model with the different subscription modes (basic, standard, advanced).

As mentioned, we have already a cooperation with two large industry vendors who are interested in extending data analytics in the proposed direction (based on the smart tagging). This proposal was related to the datasets already received from potential customers, so that the business impact of this proposal is very huge. It helped in understanding what is the quality of analysis and quality of services that can be offered to customers

## 5.2 Market: big data for quality control

Although the expansion of the big data approaches have influenced data processing in companies significantly, their applications in the domain of the quality control and monitoring are still inadequate, especially because of the dynamic nature of the quality monitoring problem and the need for very efficient computation. According to analysts, the area of (dynamic) process monitoring is one of the most promising domains for applying big data technologies in the industry, but still without the mainstream, commercially available solutions. Therefore, Qualytics aims to close the gap between the industry need and the available technologies for data-driven, dynamic monitoring of process variations (anomalies/unusualities) in manufacturing systems, with the focus on providing it as an affordable solution (SaaS).

The market predictions are very promising: According to a recent study for the EC DG CONNECT[1], the number of IoT connections within the EU28 will increase from approximately 1.8 billion in 2013 (the base year) to almost 6 billion in 2020, with a market value of €1,181 billion in 2020, driving the demand for real time analytics of massive sets of data.

From the exploitation point of view, we see the TIS platform as an enabler of a general dynamic tagging approach. It means that TIS platform will support the collection (and preparation) of the measured data which will be further processed by our data analytics modules:
1) learning module, which will learn the models of the usual behavior based on the collected past data and data from smart tagging process
2) real-time detection module, which will "compare" real-time data and the models learned in 1) in order to make early warnings regarding quality control.

Regarding the exploitation in the case of home appliance market:

1) we used our ongoing work with Whirlpool in the production of portable functional testing devices to demonstrate the potential for the usage in the maintenance service (home operation/maintenance).

2) in parallel, we would like to offer a service (SaaS) for providing:
a) the integration of the data from functional tests (factory level) and the data from the operation ("home/usage level") and
b) the data analytics on this dataset.
For a) we already have a general-purpose framework for the factory level.
For b) we will use D2Lab functionalities.

The business model for B2B will be based on the subscription fees (different levels: normal, advance, premuim).
We can envision also B2B2C model where we will offer this service to the customers of some home appliance vendors (revenue stream will be based on the subscriptions).

## 5.3 Innovation: Data-driven Digital Twins

It is important to mention that, from the business point of view, the proposal contributes to the novel concept of the Digital Twin for the maintenance of home appliances. The approach focuses on the creation of Digital twins through a novel concept of *DigitalTwinization* of "non-

[1] "Definition of a Research and Innovation Policy leveraging Cloud Computing and IoT combination" (SMART 2013/0037)

smart devices[2]", which can be seen as an approach for their retrofitting[3], esp. from the point of view of enabling sensing of the values of various parameters. Indeed, by having this new sensing, done through smart tagging, additional data related to the monitoring of the system behaviour is collected. This process can also support the real-time classification of the system behaviour (anomalous, usual), based on the model learned in the data analytics.

In our existing work we have defined the concept of data-driven Digital Twins, as virtual replicas that are generated out of available data. Although very applicable in manufacturing in general, there is still a gap in the development of twins for the maintenance of home appliances

The main problem is the availability of the data for understanding the behaviour of a device since it (usually) requires sensing of some parameters of the device. We have developed a new approach that is based on replacing expensive sensing on the device level with the data analytics on the edge. The approach consists of several steps:

1. Learn model from past data
2. Develop smart tag that can represent the knowledge from the model
3. Read periodically the tag and check the validity
4. If gap and problem with the device then record an issuee
5. Feed the information back to the assembly, close the fedback loop
6. If false positive, check the model learned

Qualytics implements the whole solution but provides innovations to steps 2 and 3.

Additionally, in the context of Digital Twins and Industry 4.0, this approach supports Retrofitting. Although Industry 4.0 is introducing the automatization / digitalization everywhere, in many companies the need for a step by step progress and improvement/upgrade of the existing machines is welcomed. We argue that for a certain type of applications (like maintenance), a rather light-weight approach with smart tags can be very practical. It is clear that such an approach should be designed properly in order to exploit the potential. Although the approach seems to be "simple" for the implementation, it requires a considerable effort in the design. Our approach can be classified as this one, with the focus on home appliance domain. The main challenge is the design of the patterns which are required for the monitoring on the edge. Usually, the complex models which are learned should be rewritten in the forma that can be supported by the smart tag technology.

The innovation approach is based on our experience from similar activities and adapted to the specificities of the Open Call proposal.

On one hand, the Open Call provided us the opportunity for experimenting with new technologies, which would be not available without Open Call. On another hand, we are driven by the innovations which have an impact in the industry, i.e. their exploitation potential should be clear.

Therefore, the design of the innovation approach was twofold:

[2] Devices which are not equipped with sensors for continuous monitoring of their vital parameters
[3] https://en.wikipedia.org/wiki/Retrofitting

- To show that the new smart tagging technology can bring innovation in the existing approaches for data analytics (disseminating the innovation potential)
- To show that this combination (smart tagging and data analytics) can have an impact on existing manufacturing processes, esp. on the quality control which is one of the most important application domains for our technologies (disseminating the exploitation potential)

Qualytics is completely aligned with our vision of using data analytics and advanced sensing for the development of a new generation of Digital Twins that are aware of the own behaviour (so called self-aware Digital Twins).

We see Qualytics as a possible approach for extending / augmenting (non-smart) devices with the sensors required for building models of the behaviour of these devices, using data analytics. In other words, Qualytics provides a new data source for getting data related to functioning of a device. It is important to notice that without having such a technology there would be not possible to get the data/values of some parameters that characterize the real-time operation of a device (e.g. temperature). It means that many activities we do for the promotion of the data-driven Digital Twin (so called D2Twin) can be related to Qualytics.

In the context of Digital Twins, the proposal has opened also the question of the importance of data-driven models in modelling the behaviour of a system.

One of the main issues is the cost for the development of such models. In the case of numerical models, human expert should create them which implies huge costs.

On the opposite, for the data-driven model, the involvement of human experts (from the domain) is not required. However, the approach requires the data analytics skills (or corresponding tools) in order to learn the model.

## 5.4 Research & Innovation: smart tagging as a part of edge processing (big data)

There is a lot of potential in exploiting the value of the smart tagging process for the edge processing an emerging area in big data technologies (as a part of Fog computing as well)

Regarding our case of using Digital twins for the maintenance of the home appliances (so called edge-based twin), an important challenge on the edge is the possibility to represent properly the model (learned on server) on the edge. Qualytics resolves two important questions in this context:

a) how precisely the model can be represent on the edge,

b) how dynamically it can be changed

We used Thinfilm tags in order to get the measurements from the devices/edge (maintenance service). Therefore, for the testing phase we have developed a new service which is specialized for the tag data, i.e. the data we obtain from the Thinfilm

This sensor belongs to the class of sensors which can be used for classifying values of some parameters based on the several (two) thresholds and some time-dependencies (durations). It is a novel approach for the quality check and there are several parameters that can be tuned in this process. These parameters are the elements to be checked in the validation, like the length (time window) of the test sequence used for learning of normal behaviour and the window for collecting real-time sequences

The main advantage is that the sensor is less expensive and can be used in different scenarios. The main challenge is that the continuous signal of a parameter should be “approximated” with the discrete values (thresholds). In principle, we interpret the tag as the source of three values (-1, 0, 1), whereas “0” means that temperature is within the thresholds, “-1” means that the temperature is below the threshold for a certain period of time and “+1” means that it is above the threshold. This can be used for any type of parameters.

# 6. Conclusions

This document provides the final report about the work done in Qualytics.

It explains what is achieved and how it can be reused for the further business development, answering on the question: what is the new service.

It analyses some of TiS technologies in the context of proposed service, answering on the quaestion: which improvement in TiS technologies would improve the new service.

It elaborates on the impact of Qualytics, showing why the project is a success.

The document summarizes the most important experience from the entire work, starting from the conceptualization, till the development and the validation of the system. The aim of the document is to clarify some of the issues which were challenging for each of the phases.

Additionally, this document reports about the importance of Qualytics for the development of our expertise in the Digital Twin domain.