PROPHESY

Platform for rapid deployment of self-configuring and optimized predictive maintenance services

DELIVERABLE

D5.2 – PROPHESY Data Visualization Portal v1

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Executive Summary

The purpose of deliverable D5.2 – PROPHESY Data Visualization Portal v1 is to describe and demonstrate the implementation of the data visualization of the PROPHESY-AR.

The data visualization is met through Dashboards implementation at the use case level. This document outlines the overall steps that were required to make a first release.

Dashboards considered in v1 are dashboards at PHI and JLR, based on sketches that were discussed between stakeholders. These Dashboards are designed using open source frameworks and implemented to run on web browsers to enable portability, readability and maintenance.

T5.2 relates to T4.1 (Automated Data Collection) and T5.1 (Visualization and AR Specifications) and the related Deliverables D4.1 (M15) and D5.2 (M12)

The document presents – at the beginning – the scope of the project and the role of this deliverable into the project. The necessary foundations for the PROPHESY-AR specifications are extracted by combining a State-of-the-Art analysis (a **Top-Down Approach**) and the results from WP2 – including Task 2.1: PROPHESY-CPS specifications, Task 2.4: Complex Demonstrator Specifications and Task 2.5: Platform Architectures and Ecosystem Specifications (a **Bottom-Up Approach**). Subsequently, the components of PROPHESY-AR and their interfaces with other PROPHESY-CPS components are defined. For the data visualization part, we define the methodology for the dashboard acquisition based on user needs. Finally, the specifications for augmented reality are presented by using a view – based approach based on the Kruchten 4+1 model.

Overall this deliverable provides to the rest tasks of the WP 5 the necessary generic specifications in order to implement the data visualization part (task 5.2) and augmented reality tasks (Task 5.3 and 5.4).

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Document History			
Version	**Date**	**Contributor(s)**	**Description**
V0.1	21/12/2018	ICARE	Initial version of the Document and contents
V0.2	28/12/2018	ICARE	Reviewed by internal collaborators
V1.0	28/12/2018	ICARE	Final version

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Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
AR	Augmented Reality
BOM	Bill of Materials
CPS	Cyber-Physical System
CTQ	Critical To Quality
DMC	Data Matrix Code – Quick Response
DTA	Digital Torque Analyser
ERP	Enterprise Resource Planning
FIS	Factory Information System
FMECA	Failure modes, effects and criticality analysis
I-DNA	Intelligent Decimation Numerical Algorithm
IoT	Internet of Things
MES	Manufacturing Execution System
MTTR	Mean Time To Repair
OEE	Overall Equipment Effectiveness
OPR	Offline Process Recorder
PdM	Predictive Maintenance
pk-pk	peak-to-peak
PLC	Programmable Logic Controller
PROPHESY System	It is the combination of the PROPHESY-CPS and PROPHESY-PdM platform
PROPHESY-AR	PROPHESY-Augmented Reality
PROPHESY-CPS	PROPHESY-Cyber Physical System
PROPHESY-ML	PROPHESY-Machine Learning
PROPHESY-PdM	PROPHESY-Predictive Maintenance
PROPHESY-SOE	PROPHESY-Service Optimisation Engine
RPN	Risk Priority Number
TTR	Time To Repair
UC	Use Case

1 Introduction

1.1 The PROPHESY Vision

Despite the proclaimed benefits of predictive maintenance (PdM), the majority of manufacturers are still disposing with preventive and condition-based maintenance approaches, which result in suboptimal OEE (Overall Equipment Effectiveness). This is mainly due to the challenges of predictive maintenance deployments, including the fragmentation of the various maintenance related datasets (i.e. data "silos"), the lack of solutions that combine multiple sensing modalities for maintenance based on advanced predictive analytics, the fact that early predictive maintenance solutions do not close the loop to the production as part of an integrated approach, the limited exploitation of advanced training and visualisation modalities for predictive maintenance (such as the use of Augmented Reality (AR) technologies), as well as the lack of validated business models for the deployment of predictive maintenance solutions to the benefit of all stakeholders. The main goal of PROPHESY is to lower the deployment barriers for advanced and intelligence predictive maintenance solutions, through developing and validating (in factories) novel technologies that address the above-listed challenges.

In order *to alleviate the fragmentation of datasets and to close the loop to the field,* PROPHESY has specified a novel CPS (Cyber Physical System) platform for predictive maintenance [See Deliverable D2.1], which shall provide the means for *diverse data collection, consolidation and interoperability*, while at the same time supporting digital automation functions that will *close the loop to the field and will enable "autonomous" maintenance functionalities*. The project's CPS platform is conveniently called PROPHESY-CPS and is developed in the scope of WP3 of the project.

In order *to exploit multiple sensing modalities for timely and accurate predictions of maintenance parameters (e.g., RUL (Remaining Useful Life))*, PROPHESY will employ advanced predictive analytics which shall operate over data collected from multiple sensors, machines, devices, enterprise systems and maintenance-related databases (e.g., asset management databases). Moreover, PROPHESY will provide tools that will facilitate the development and deployment of its library of advanced analytics algorithms. The analytics tools and techniques of the project will be bundled together in a toolbox that is coined *PROPHESY-ML* and is developed in WP4 of the project.

In order *to leverage the benefits of advanced training and visualisation for maintenance,* including *increased efficiency and safety of human-in-the-loop processes* the project will take advantage of an Augmented Reality (AR) platform. The AR platform will be customised for use in maintenance scenarios with particular emphasis on remote maintenance. It will also be combined with a number of visualisation technologies such as ergonomic dashboards, as a

means of enhancing workers support and safety. The project AR platform is conveniently called *PROPHESY-AR.*

In order *to develop and validate viable business models for predictive maintenance deployments,* the project will explore optimal deployment of configurations of turnkey solutions, notably solutions that comprise multiple components and technologies of the PROPHESY project (e.g., data collection, data analytics, data visualisation and AR components in an integrated solution). The project will *provide the means for evaluating such configurations against various businesses and maintenance criteria,* based on corresponding, relevant KPIs (Key Performance Indicators). PROPHESY's tools for developing and evaluating alternative deployment configurations form the project service optimisation engine, which we call *PROPHESY-SOE.*

1.2 PROPHESY WP5 Overview

WP5 (PdM visualization and Augmented Reality Services for Remote Expert Support) is devoted to providing visualization and augmented reality (AR) services for remotely-supported predictive maintenance processes, as a means of improving the efficiency of maintenance services and increasing maintenance employees' productivity. Visualization will be provided at a machine, component and production system level, the AR solution will be part of OCULAVIS support and knowledge sharing platform. The main objectives of WP5 include:

- To specify and implement user-centric visualizations of the condition of machines, tools, components and production systems, including relevant predictions derived from PROPHESY-ML.
- To provide a platform for training remotely employees and sharing knowledge across maintenance stakeholders based on the visualization and AR technologies of the project.
- To specify and implement the PROPHESY-AR technology of the project, which will leverage AR in order to support remote maintenance services.

1.3 PROPHESY Task 5.2 Overview

Task 5.2 aims at implementing user-friendly visualizations in the form of dashboards, based on the specifications of the previous task. The implementation will leverage the data visuals portal of ICARE, which facilitates the visualization and sharing of maintenance data. From a technical perspective, the visualizations will be integrated over the PROPHESY-CPS platform and the PROPHESY-ML data analytics assets implemented in WP3 and WP4 respectively. PROPHESY's data sharing and data interoperability framework will enable the sharing of visualization across stakeholders, including manufacturers, machine vendors and PdM solution providers.

D5.2 also has a connection to Task 4.1 through the use of the PROPHESY-DM for retrieving data that has been automatically collected from the various sources of data made available by the PROPHESY-ML and the PROPHESY-CPS.

1.4 Document scope and structure

The current document is structured as follows:

Section 1. **Introduction**: details the document context and purpose.

Section 2. **Methodology and Implementation:** describes the methodology for designing and implementing the Dashboards for the Use Cases

Section 3. **Dashboards for the Use Cases:** gives an overview of the Dashboards, their user stories and their first sketches.

Section 4. **Conclusions**: provides the conclusion of this document and point out the next steps.

2 Methodology and implementation

2.1 Reminder from D5.1

In terms of PROPHESY architecture, the PROPHESY-AR is a crosscutting layer which crosses PROPHESY-CPS and PROPHESY PdM. Figure 1 reminds the PROPHESY-AR components.

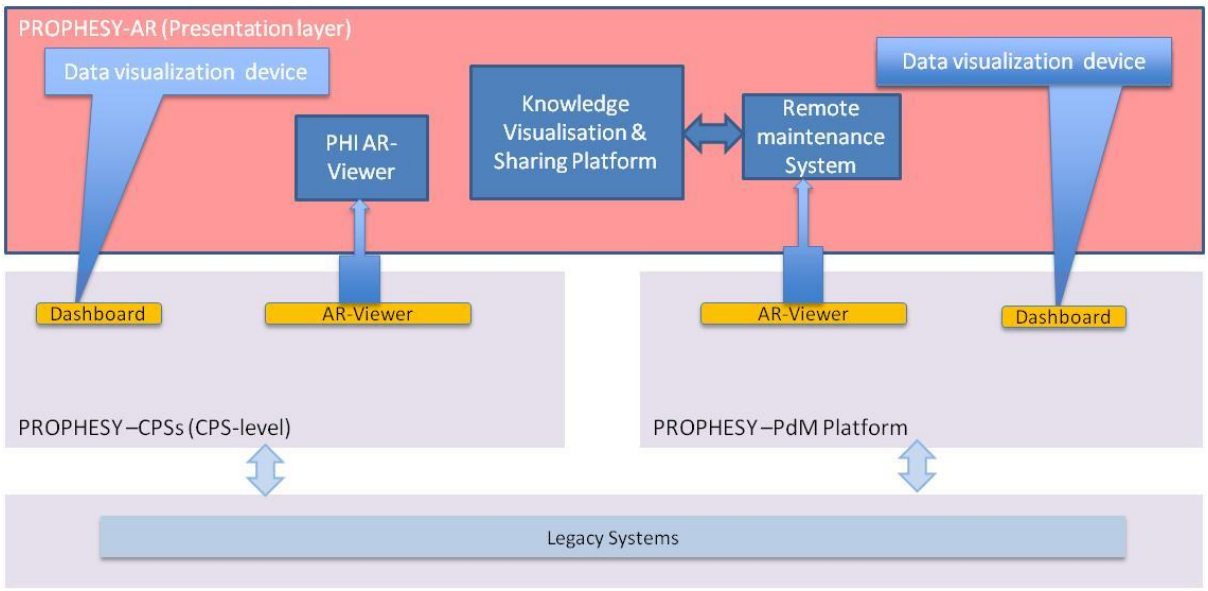


Figure 1 PROPHESY – AR components

Table 1 Provides a brief summary of the components.

Table 1 PROPHESY-AR Components & Description

Component	Description
Data visualization*	This component is responsible for visualizing information to users involved in the maintenance process. It displays information for tools, indicators useful for the maintenance team in the workshop and for the maintenance management
CPS Message bus	retrieves data coming from CPS assets (such as sensors, machinery) and local machine learning algorithms (PROPHESY-ML -HF/ML). Data is presented as topics in the CPS message bus
PdM message bus	retrieves data coming from connected CPS to PdM platform central machine learning algorithms (PROPHESY-ML -LF/ML). Data is presented as topics in the PdM message bus
PHI-AR – Viewer	provides relevant maintenance knowledge to technicians using augmented reality and acts as a maintenance assistant

Remote – AR service (and client)	allows remote training and maintenance support. A machine manufacturer can help the customer operator or maintenance engineer
Platform repository	retrieves data come from legacy systems (Pdfs, csv, files etc.).

*It is important to note that D5.2 deals with the Data visualization component, but not the other listed components of Table 1.

2.2 Tools and methodology

PdM dashboards are one of the outputs of the PROPHESY project and will be implemented in task "T5.2". External PROPHESY stakeholders will be delivered with key components that will enable to make decisions based on a mix of information from various databases and learning algorithms.

The dashboards implementation is a 2 steps process that leads to 2 versions (D5.2 and D5.3). The first version aims at achieving a first round of mock-ups, identified constraints, data sources and end devices, describing the expected features with a clear objective to begin version 2 with an implementation such that it can be further deployed and connected to the enterprise information system.

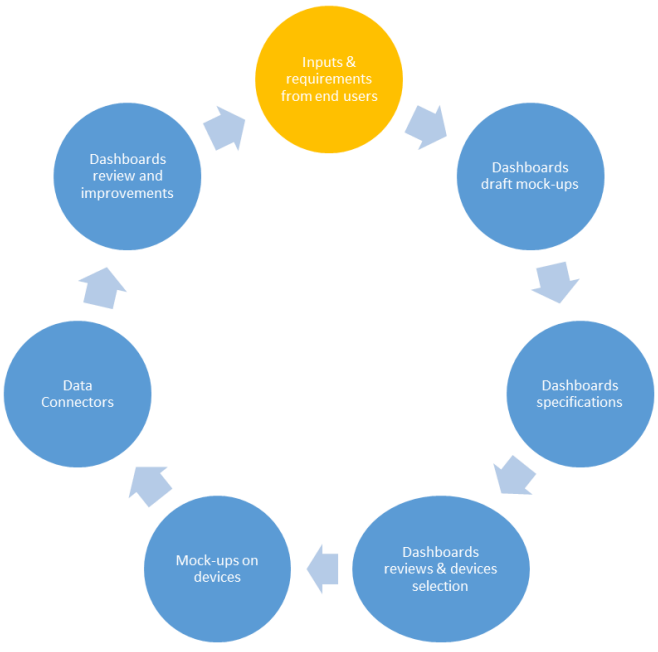


Figure 2 Dashboard Agile Implementation

The implementation uses open source software frameworks and Python. This choice was made because Python is open source, cross-platform and is the backend programming language for I-see (https://isee.icareweb.com). Making use of commonly used open source

software also ensures maintainability and sufficient documentation for help and support. For further details about the implementation process, please refer to D5.1 (M12).

3 Dashboards for the use cases

3.1 PHI Dashboards for UC1 & UC2

For v1, it has been agreed that data would be uploaded to a Sharepoint Platform in a manual way. This would ensure that only relevant data would be made available to partners and would be accessible by the partners of the consortium. More information about the Automatic Data Collection can be found in D4.1 (M15). Dashboard data is based on dummy data on screenshots shown in the next sections.

3.1.1 Dashboard UC1

At use case 1, here's the summary of the user story:

- Name: Dashboard at cold forming press
- Visualization devices: Display
- Role, person: Machine operator
- Process description supported by dashboard: The operator can easily visualise the predicted RUL. Before starting a shift, he/she can check if a part will require maintenance soon or not.
- Indicators used in the dashboard: Tool assembly RUL (hours & strokes) till maintenance

An example of the display is provided on Figure 3.

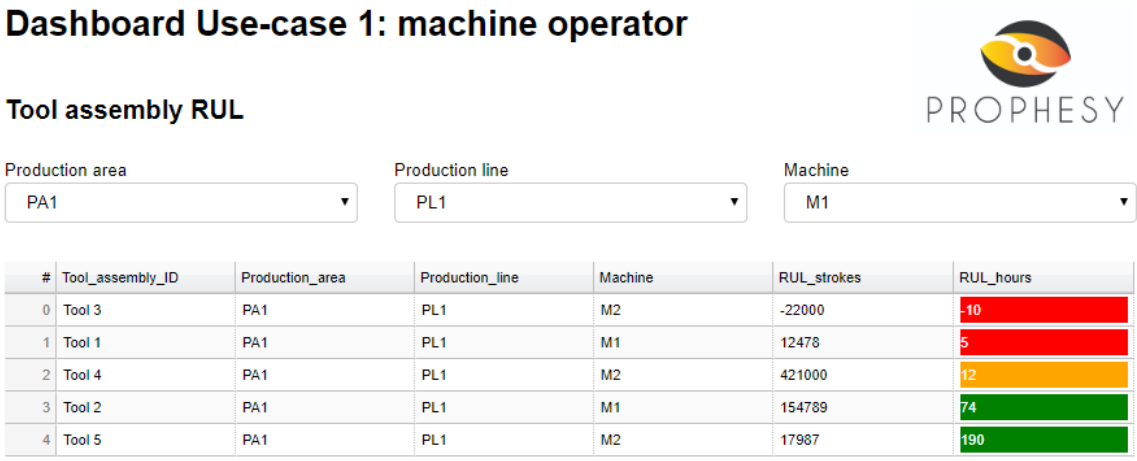
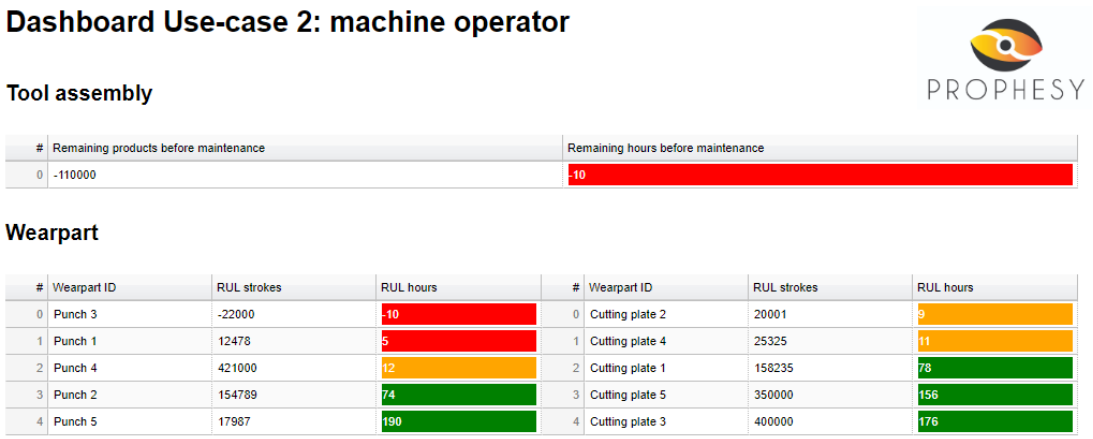


Figure 3 Dashboard screenshot for UC1

3.1.2 Dashboard UC2

At use case 2, here's the summary of the user story:

- Name: Dashboard at cutting-out machine
- Visualization devices: Display
- Role, person: Machine operator
- Process description supported by dashboard: The operator can easily visualise the predicted RUL. Before starting a shift, he/she can check if a part will require maintenance soon or not.
- Indicators used in the dashboard:
  - Predicted RUL (punch). Per position 1 to 5
  - Predicted RUL (cutting plate). Per position 1 to 5
  - Predicted RUL (tool assembly)



Dashboard Use-case 2: machine operator

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Tool assembly

#	Remaining products before maintenance	Remaining hours before maintenance
0	-110000	-10

Wearpart

#	Wearpart ID	RUL strokes	RUL hours	#	Wearpart ID	RUL strokes	RUL hours
0	Punch 3	-22000	-10	0	Cutting plate 2	20001	9
1	Punch 1	12478	5	1	Cutting plate 4	25325	11
2	Punch 4	421000	12	2	Cutting plate 1	158235	78
3	Punch 2	154789	74	3	Cutting plate 5	350000	156
4	Punch 5	17987	190	4	Cutting plate 3	400000	176

Figure 4 Dashboard screenshot for UC2

3.1.3 Maintenance Management Dashboards for UC 1 & UC2

- Name: Maintenance Management Dashboard
- Visualization devices: Display
- Role, person: Mechanics, Maintenance Management
- Process description supported by dashboard:
  - Useful maintenance efficiency indicators for maintenance teams in their workshop and daily management
  - Useful maintenance efficiency indicators for the maintenance management
- Indicators used in the dashboard:
  - Daily Indicators (see Figure 5)
    - MTTR and Average throughput time
    - % first time right

- Number of reworks

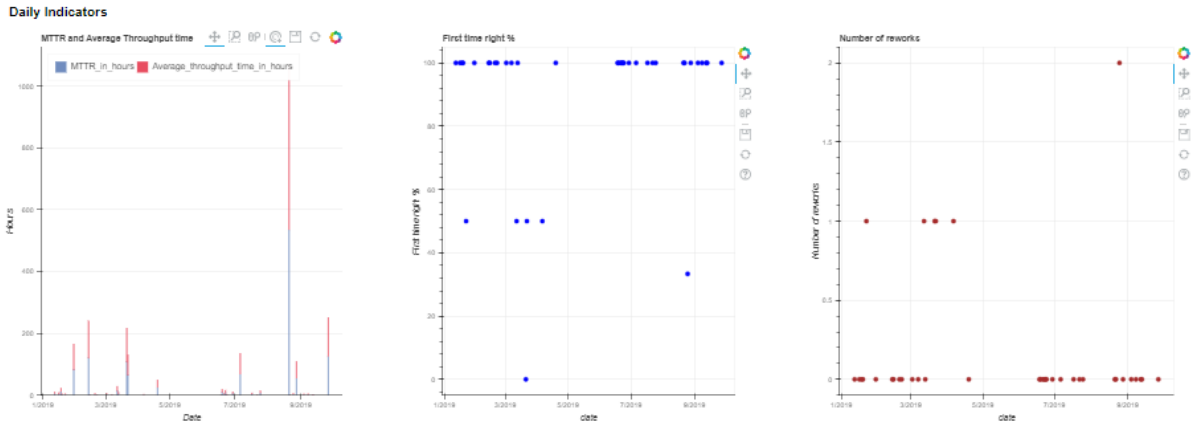

Figure 5 Maintenance Management Dashboards - Daily Indicators screenshot

- Weekly Indicators (see Figure 6)
  - OEE
  - % Preventive maintenance ratio

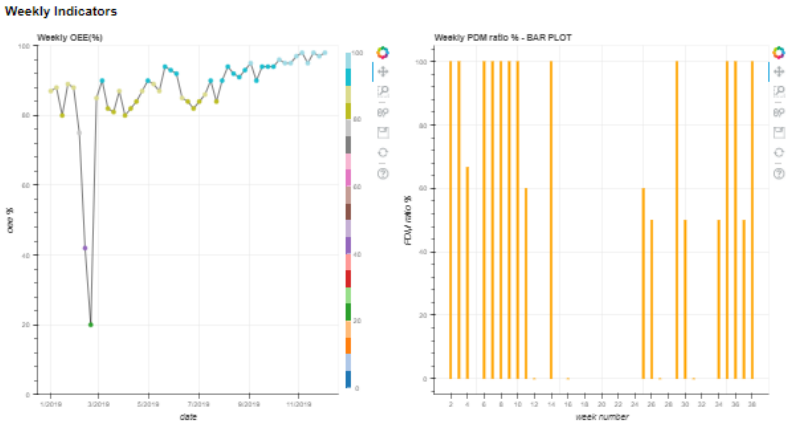

Figure 6 Maintenance Management Dashboards - Weekly Indicators screenshot

- Monthly Indicators (see Figure 7)
  - Inventory value
  - Monthly maintenance cost

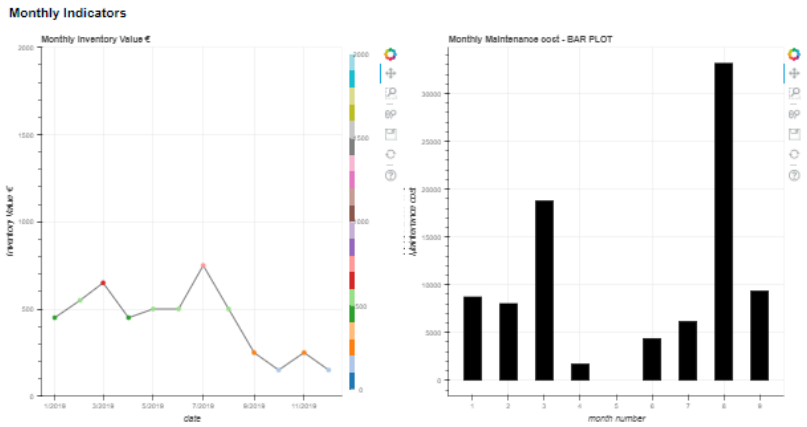

Figure 7 Maintenance Management Dashboards - Monthly Indicators screenshot

The overall picture is displayed on one full page. See Figure 8 for a complete overview.

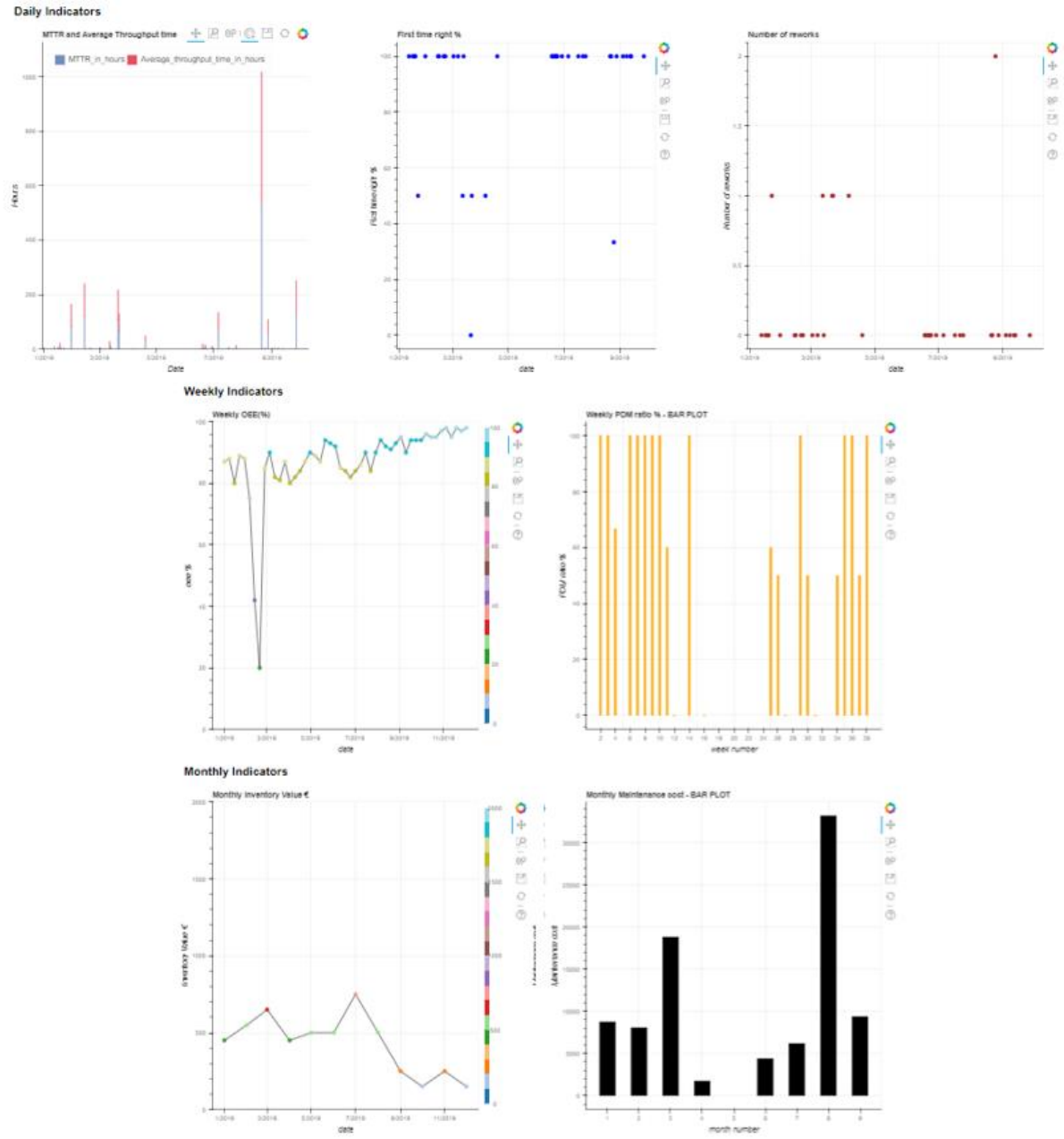

Figure 8 Maintenance Management Dashboard - overall layout screenshot

3.2 JLR Dashboards

The process for the UC 4 & UC5 dashboards is the same than for the previous UC1 & UC2 dashboards. However, the user story is different because of the different processes and focus.

3.2.1 Dashboard UC4

At use case 4, here's the summary of the user story:

- Name: Critical Machine Parts
- Visualization devices: Display
- Role, person: Operator, maintenance manager
- Process description supported by dashboard: The operator and the maintenance manager can both easily visualise the predicted RUL on a machine
- Indicators used in the dashboard:
    - RUL of the machine
    - Alarm (if any) with alarm source and timestamp of alarm

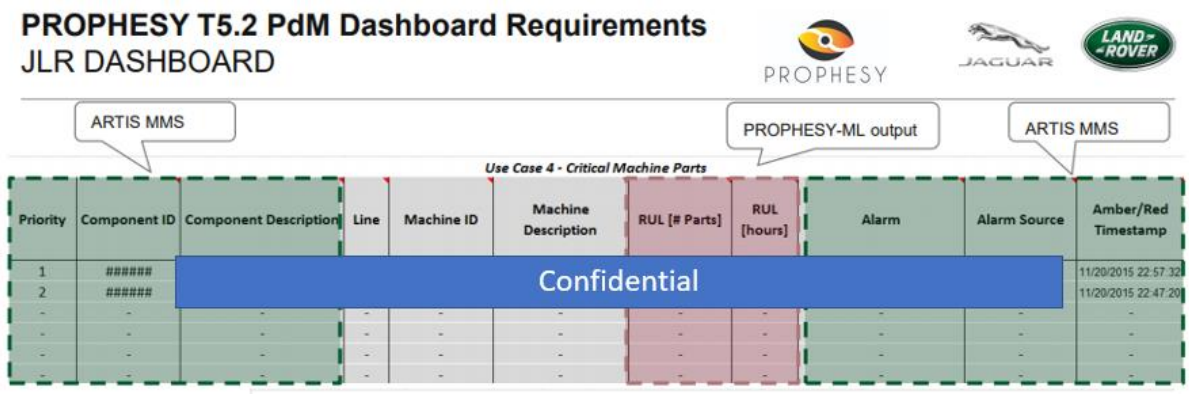

Figure 9 Dashboard for Use Case 4

3.2.2 Dashboards UC5

At use case 5, here's the summary of the user story:

- Name: Cutting tools dashboard
- Visualization devices: Display
- Role, person: Operator, maintenance manager
- Process description supported by dashboard: The operator and the maintenance manager can both easily visualise the predicted RUL on a machine
- Indicators used in the dashboard:
    - Part ratio (number of parts manufactured with the tool compared to the target number of parts)
    - Cost per Unit of tool and per parts produced

- Cost of tool per unit increase

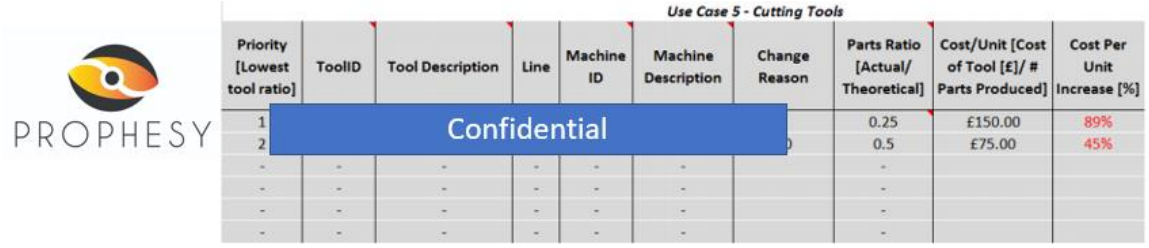

Figure 10 Dashboard for Use Case 5

When clicking on a tool ID, the user loads another screen displaying the number of changes of this tool on all machines the tools have been installed previously and for what reason code.

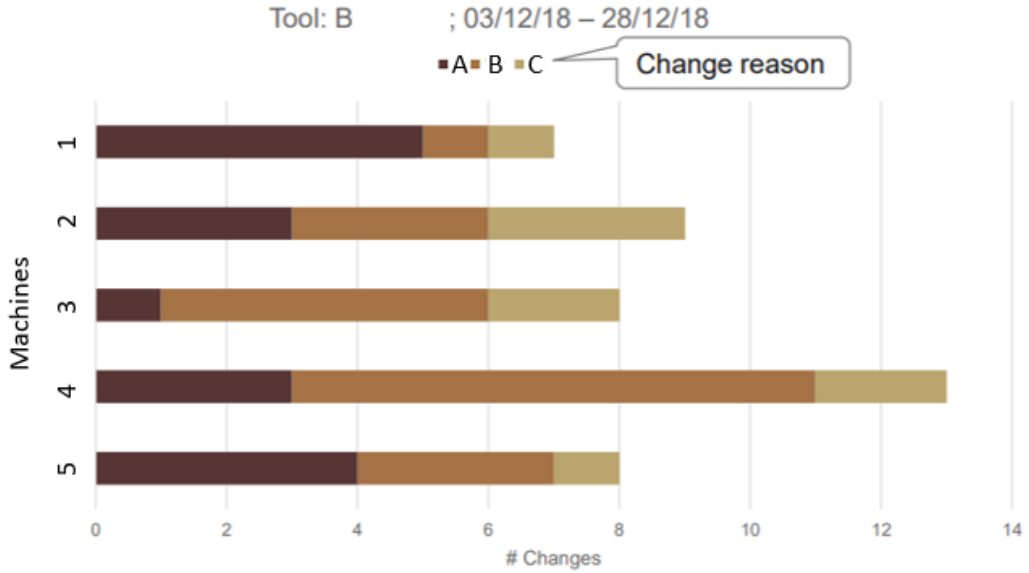

Figure 11 Dashboard for Use Case 5 – Tool ID B details

4 Conclusion and Future Outlook

WP5 is devoted to providing visualization and augmented reality services for remotely-supported predictive maintenance processes, built into the PROPHESY-AR architecture. D5.2 is about the data visualisation portal, leading to dashboards dedicated to the use cases and based upon data collected at the factory level and fed into the PROPHESY framework.

Based on discussions with the end users and other PROPHESY partners at the PROPHESY-ML, PROPHESY-PdM and PROPHESY-CPS level, it was possible to design and implement a first version of the PROPHESY dashboards for the use cases.

For version 2 (D5.3, M27), it is expected to refine the dashboards using new PROPHESY-ML outputs to feed the Dashboards were this information is relevant, such as in use case 1, use case 2 and use case 4.