Testing innovative predictive management system for bus fleets:
outcomes from the Ravenna case study

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EBSF_2 is a project funded by the European Commission within Horizon 2020.

The goal is to develop a new generation of bus systems, by increasing efficiency and attractiveness of this mode.

Several working areas testing innovative technological solutions, among these: Intelligent garage and predictive maintenance.

Tests on intelligent garage focus on the definition of new algorithms or software for predictive maintenance, the use of innovative tools for bus depot and provides new ways to manage bus fleets with new maintenance procedures.

Bari September 14th, 2016
Within EBSF_2, the objective of the Ravenna demonstration is the implementation of a maintenance software to analyze data coming from quality sensors for lubricants to assess the engine oil quality and therefore to detect potential or breakdowns and promptly/when needed replace spare parts.

It is also possible to understand the causes that have influenced or produced the bad quality of the oil.
Objectives

• Checking up the engine oil and having real time information on the oil quality

✓ Estimate the remaining life time of some engine components
✓ Mitigate obnoxiousness of vehicle CO₂ emissions
✓ Allow significant cost savings by optimizing the oil change frequency or prevent early replacement of some components
✓ Contribute to comply with the IT standard EN 13149 part 7/8/9 (introduction of interoperable IT systems in fleets already operational)
How it works

The system relies on the implementation of a predictive maintenance software aimed at providing real time information on the quality of the engine oil via a specific oil quality sensor, and an additional filter, or purifier.

This enables a time-based trend assessment of the qualitative attributes of the engine oil (conductivity, temperature, amount of water, etc.) and on-line reporting of their values. The sensors also alert when values are out of range.
How it works

Predictive Controller

FMS Gateway

Back-office

On-Board data collection
Converter/Import tool
Diagnostics
Monitoring

GPRS

ITxPT Compliant

Predictive Maintenance
Back-Office (Officina)

Pluservice

Pluservice

Garage Manager

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Oil Quality Sensor (MEL-System)

EOLS Filter (MEL-System)

Pressure Sensor

VIDAC Metatronix

METAC

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The EBSF_2 test scenario

Six vehicles were equipped with data collectors and lubricant sensors that are able to send the information to the on-board data collection system. In addition, some vehicles are equipped with the additional purifier, to test the lubricant quality, compared with that of the vehicles without the filter.
The EBSF_2 test scenario

Demonstration activities are carried out in *real operational life situation* by in collaboration with the local public transport operator **START Romagna**

<table>
<thead>
<tr>
<th>Lines involved</th>
<th>Staff involved</th>
<th>Vehicles involved</th>
<th>Area</th>
</tr>
</thead>
</table>
| 13 urban lines | 184 drivers 8 mechanics | 3 natural gas powered buses  
Brand: BREDA  
Model: M 231/GNC4 CU | Flat urban area |
| 14 extra-urban lines | 305 drivers 12 mechanics | 3 diesel powered buses  
Brand: IRISBUS  
Model: 399EL82 (My Way) | Sub-urban area |

*Bari September 14th, 2016*
Data acquisition: results achieved

✓ Results of the oil sampling also checked by an external laboratory

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Data acquisition: results achieved

✓ For each component, it is possible to analyze the concentration over time
Data acquisition: Result achieved
✓ Specific function to analyze the temporal trend of the variables/data acquired from the on-board unit
✓ The system collects data and calculates values for each vehicle
## Operational Performance: Results achieved, thus far

<table>
<thead>
<tr>
<th>KPI</th>
<th>Before – vs – during Variation (%)</th>
<th>Expected Performance Target (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating costs per vehicle per 10,000 km (energy not included)</td>
<td>7.49</td>
<td>-10</td>
</tr>
<tr>
<td>Energy costs per vehicle per 10,000 km (fuel, energy)</td>
<td>-12.36</td>
<td>-5</td>
</tr>
<tr>
<td>Costs of maintenance staff per vehicle per 10,000 km</td>
<td>19.6</td>
<td>-10 ÷20</td>
</tr>
<tr>
<td>Costs per spare parts purchase per vehicle per 10,000 km</td>
<td>-1.71</td>
<td>-10 ÷20</td>
</tr>
<tr>
<td>Oil required per vehicle per 10,000 km</td>
<td>-31.8</td>
<td>-10 ÷20</td>
</tr>
<tr>
<td>Total and amortization costs per vehicle per 10,000 km</td>
<td>-15.06</td>
<td>-5 ÷10</td>
</tr>
<tr>
<td>Average maintenance time per vehicle per 10,000 km</td>
<td>0</td>
<td>-10%</td>
</tr>
<tr>
<td>Breakdowns per vehicle per 10,000 km</td>
<td>-8.08</td>
<td>-15%</td>
</tr>
<tr>
<td>Effort for data management</td>
<td>17</td>
<td>-5</td>
</tr>
<tr>
<td>Energy (fuel) consumption per vehicle and km</td>
<td>0</td>
<td>-5</td>
</tr>
<tr>
<td>Influence of repair activities</td>
<td>23</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>
## IT reliability: Results achieved, thus far

<table>
<thead>
<tr>
<th>KPI</th>
<th>Unit of measurement</th>
<th>Reference values</th>
<th>Test value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP messages published on the IP network compliant with IT standards</td>
<td>Daily amount of events/vehicle</td>
<td>H=&gt;80% of compliant events M=between 80% and 60% L=&lt;60%</td>
<td>H😊😊</td>
</tr>
<tr>
<td>TSR Transaction Success Rate, including localisation update, event</td>
<td>Daily amount of TSR per vehicle</td>
<td>H=&gt; 90% of success rate M=between 90% and 75% L=&lt;75%</td>
<td>M😊</td>
</tr>
<tr>
<td>from OnBus AVLS and events from Service Control</td>
<td>Seconds</td>
<td>H=&lt;5 s M=between 5s and 30 s L=&gt; 30s</td>
<td>L</td>
</tr>
<tr>
<td>Latency (from Bus to Service Control - to Bus from Service Control)</td>
<td>Daily amount of alerts-alarms in</td>
<td>H=&lt;20% M=between 20% and 40% L=&gt;40%</td>
<td>H😊😊😊</td>
</tr>
<tr>
<td></td>
<td>vehicle and back-office</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back-office vs on-board data</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**key**
- H = high
- M = Medium
- L = Low
Environmental Potential: Reducing the Toxicity of Emissions

Emissions sources of heavy metals such as cadmium, copper, mercury and lead are all associated with fuel combustion and a part of them is due actually to lubricant consumption.

However, lubricants consumption is usually calculated according to mileage and so are emissions.

In the case of Ravenna, the predictive system, by enabling the reduction of breakdowns, contributes to increase mileage (and therefore emissions potential) as the amount of dwell time at workshop maintenance is optimized. But...
Environmental Potential: Reducing the Toxicity of Emissions

but this can be mitigated by their decreased toxicity due to a diminished content of harmful heavy metals, achievable by the oil filters. Simulations (COPERT V) on two diesel-fueled vehicles, equipped with the sensors and the oil filters, show that a 5%-reduced content of heavy metals in the oil can achieve a 0.01% reduction in the CO$_2$ emissions related to lubricants.

If upscaled to the whole fleet (62 vehicles) and regular urban operations, and assuming a more modest reduction of 10% of oil consumption, then it is possible to save 0.56 tons of CO$_2$ emitted yearly, just by equipping the vehicles with the filters and sensors.
Environmental Potential: Optimizing the Management of Waste

The EC Directive 2008/98 includes under the waste prevention “umbrella” measures to reduce the content of harmful substances in products.

According to the first outcomes, the installation of a purifying filter on the two vehicles might enable a postponement in the oil change of around 10,000 km, per single vehicle, i.e. to avoid one operation of oil change in every four years, per vehicle.

If upscaled to fleet level, it is possible to prevent from disposing around 15 tonnes of oil every four years.
Keep tracks of the final results.....

http://ebsf2.eu/

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....and participate in the evaluation process