SE:Kond2Life project
Work Package 2:

Sensor data to support the remanufacturing process

Report Summary, 2022-05-10

Background

Remanufacturing is an efficient strategy to close-the-loop on automotive parts by extending their useful lives. The ability to exploit the economic and environmental benefits of remanufacturing practices depends, among other factors, on the condition of the components at the End-of-Life (EoL) of the vehicle.

In recent years, there has been an increasing interest to collect and process sensor data from across the vehicle's lifecycle for prognostics and health management purposes. However, the potential to further utilize this data at the End-of-Life of the vehicle has so far been largely overlooked.

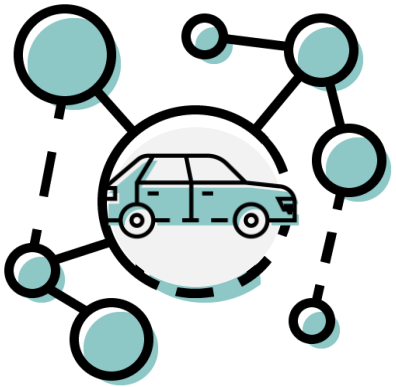
The aim of this study was to address this gap by investigating how on-board sensor data can be used to support the process of inspection and condition assessment of parts from EoL vehicles. Valuable input from the industrial partners (E.g. Volvo Cars, ECRIS and Jönköpings bildemontering) as well as a review of previous and ongoing research within this field have been an important basis for the work.

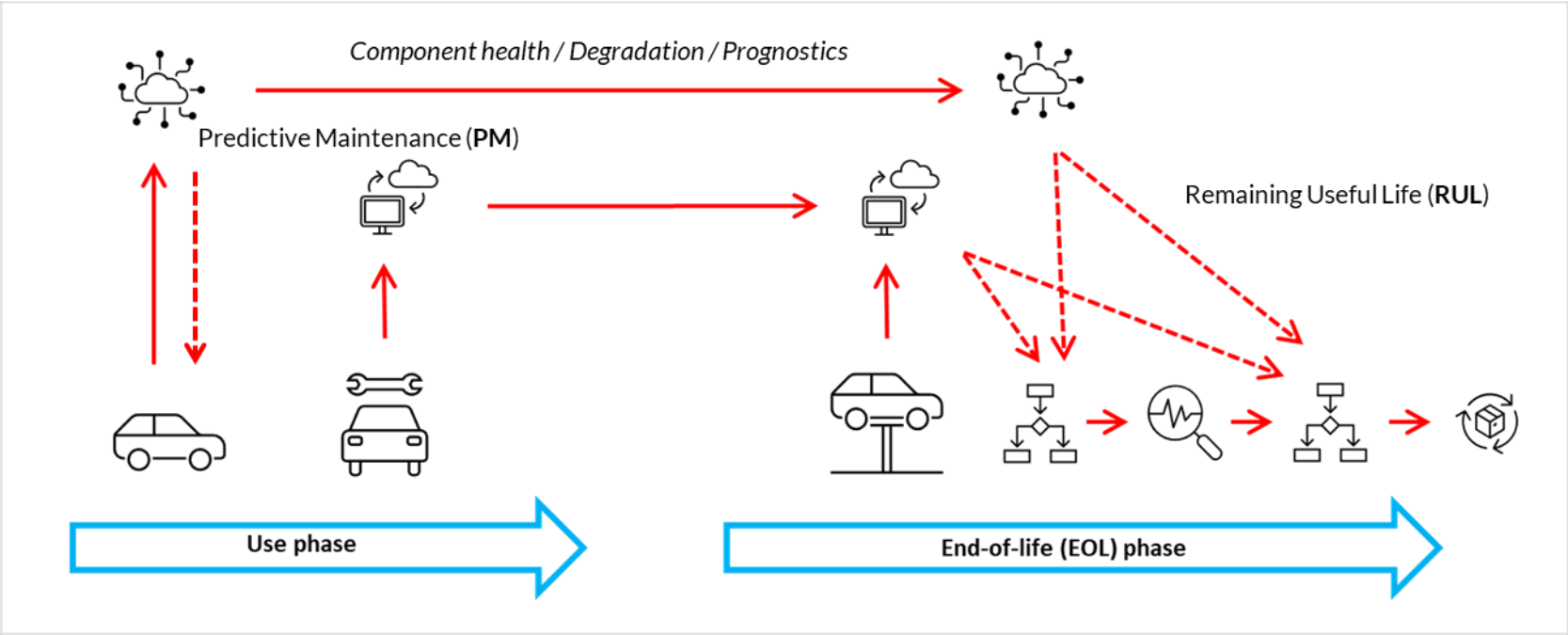
This study is part of the project "SE:Kond2Life – Ecosystem for reuse of automotive components" which is focused on demonstrating how an ecosystem of circular value chains can be realized, in combination with a business logic for sustainable reuse of automotive components over multiple product life cycles.

Main highlights

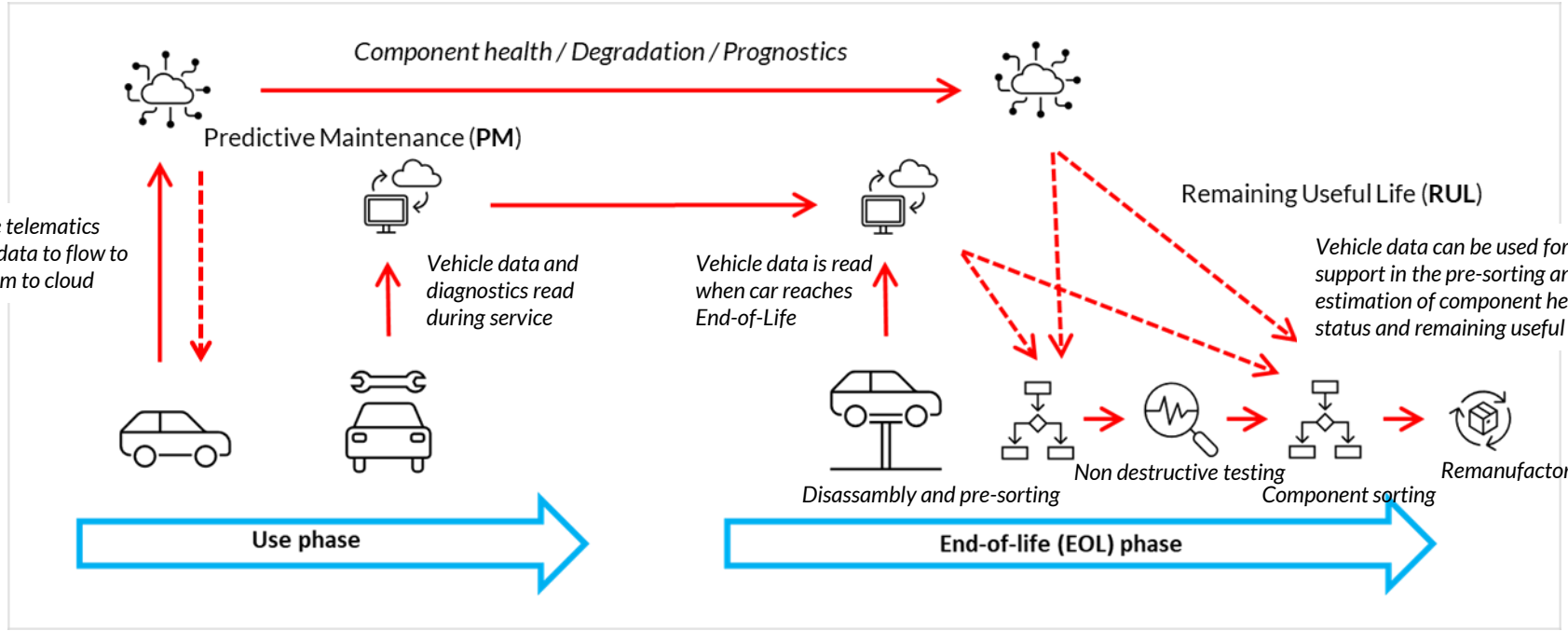
A literature review of previous research and interviews with industrial partners in the project led to the following observations:

- With a few exceptions, the use of sensor data from across the vehicle's lifecycle at the end-of-life of the vehicle has been largely overlooked so far.
- Sensor data collected and analysed during the use phase of the vehicle for the purpose of predictive maintenance can prove also valuable to support the remanufacturing process at the end-of-life of the vehicle, for instance through condition indicators for the vehicle's components, such as remaining useful lifetime (RUL).
- A lifecycle approach of sensor data and synergies with other advanced vehicle health capability concepts, such as integrated vehicle health management (IVHM), has a good potential to support enhanced remanufacturing of automotive parts.





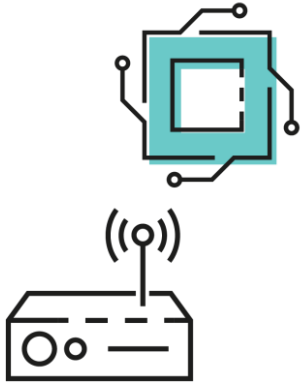
Illustrative schematic of sensor data flows during the use phase (through e.g. On-Board Diagnostics (OBD) port and telematics), and potential use (dashed arrows) for decision support in the pre-sorting and/or classification of the components condition during the disassembly and remanufacturing process at the End-of-Life phase.



Illustrative schematic of sensor data flows during the use phase (through e.g. On-Board Diagnostics (OBD) port and telematics), and potential use (dashed arrows) for decision support in the pre-sorting and/or classification of the components condition during the disassembly and remanufacturing process at the End-of-Life phase.

Sensor data & remanufacturing: Selected research results

Remanufacturing of automotive parts is of growing importance within the automobile industry [Casper 2018; Casper 2021]. The ability to exploit the economic and environmental benefits of remanufacturing practices depends, among other factors, on the condition of the components at the End-of-Life (EoL) of the vehicle. Sensor data collected during the utilization of the vehicle could provide valuable insight to improve the assessment of the EoL component's condition.



The following slides provide examples of research studies related to the utilization of on-board sensor data to assess the components' health condition, either for the purpose of remanufacturing at the end-of-life of the vehicle, or for predictive maintenance during the use phase.

The body of knowledge related to the latter case provides a valuable resource for condition-based models, algorithms and indicators that could be used to support the process of inspection and condition assessment of parts from EoL vehicles.

Sensor data & remanufacturing: Selected research results

Logged Vehicle Data & Remanufacturing:

The most relevant published research identified in this study in relation to the remanufacturing of automotive parts is the work by A. Kroner and his colleagues, who proposed a data analysis approach based on the data from the vehicle's ECU (Electronic Control Unit) to predict the probability for reuse of mechanical components. [Kroner 2020]

The case study was the automatic car transmissions, and the model was applied on a planetary gear transmission from Mercedes-Benz AG. As pointed out by Kroner et al., components which are not reusable have to be recycled after going through the cost intensive process steps disassembly and cleaning. It would be beneficial to sort out non-reusable components as early as possible in the process. The question addressed was if the inner condition of selected components can be predicted with load data from the ECUs to facilitate preselection. The ECU-data with real loads of the individual transmission were used for a pre-sorting process prior to the remanufacturing process. A model structure was proposed to give a probably of a positive inspection of the transmission components, especially the planetary gear sets. The model suggested by the authors lead to a recommendation with higher likelihood for the remanufacturing process.

Sensor data & remanufacturing: Selected research results

Predictive maintenance:

Predictive maintenance describes an approach to equipment management that focuses on exploiting sensing, inspection, and maintenance data to forecast future degradation state, remaining-useful-life, or similar quantity characterizing expected future performance of the equipment. Such forecasts are then used to optimize maintenance planning, supply chain, and other maintenance, design, and engineering activities. [Miller 2019]

The collection and analysis of the vehicle's sensor data for predictive maintenance is an integral part of the prognostics and health management strategies in automotive. [Nguyen 2019]

Table 1 (next slide) shows examples of datasets used for predictive maintenance of a range of automotive components.

Table 1 Examples of data-driven predictive maintenance in automotive sector.

Data sources	Components	References
• Logged Vehicle Data (LVD) • Data trouble codes (DTCs) • Vehicle Service Records (VSR) (a.k.a Vehicle maintenance database, a.k.a. Repair information/data) (VSR • Vehicle Data Administration	Air compressor, air suspension component (air bellow), powertrain component (turbocharger) in heavy duty trucks (AB Volvo)	Nowaczyk 2013 Pritz 2014 Falkovén 2017 Pirasteh 2019 Berck 2019
• CAN-bus signals • Extra-sensor signals	Driveline components in Heavy duty construction machines (Volvo Construction Equipment Wheel Loader)	Källström 2018
• LVD • Contract and Warranty claims data	Trucks (DAF)	Lemmen 2019
• Data from the ECU	oxygen sensor in vehicles with combustion engine	Giobergia 2018
• CAN-logger that record the in-vehicle signals	Exhaust Gas Recirculation (EGR) cooling system (powertrain component) in vehicles with diesel engines	Sass 2018 Sass 2020
• Engine Controller Data	Diesel engine	Nixon 2018
• OBD data	Engine oil service life	Siegel 2014

Potential challenges

Despite the similarities in the need to assess a component's condition in both predictive maintenance and EoL remanufacturing approaches, and hence the potential synergy in using the same sensor data in both applications, several potential obstacles specific to the automotive sector need to be addressed in order to benefit from using the vehicle's sensor data to support the remanufacturing process are. Some of the identified challenges in literature are:

- Complexity of the vehicles and their associated usage environment. The real load distribution on the components may be difficult to estimate from sensor data since the driving operation may vary depending on the weight of the vehicle (incl. passengers, luggage and trailer operation), the road profiles, and the driver behavior.
- The specifics of automotive industry make fault prediction a more challenging problem than in other domains: often prior research considers a case where continuous monitoring of devices is possible. In contrast, continuous monitoring of vehicles is difficult due to, for example, current limitations in connectivity and in on-board data storage & management.
- Even though Machine Learning (ML) algorithms can discover patterns that are too complex for humans to capture, these methods are still heavily dependent on careful data cleaning and feature extraction.
- Possible mismatch between value components in use-phase (predictive maintenance) and EoL-phase (remanufacturing)
- Data ownership and data infrastructure

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This study is part of the project

SE:Kond2Life – Ecosystem for reuse of automotive components

The aim of the SE:Kond2Life project is to demonstrate how an ecosystem of circular value chains can be realized, in combination with a business logic for sustainable reuse of automotive components over multiple product life cycles.

Project partners:

RISE Research Institutes of Sweden, Linköping University, Swerim, ECRIS, Jönköpings bildemontering, Volvo Cars, Prestando Holding, FKG, Bos NDT Solution, Borgstena, Havd Group.

More information:

https://www.ri.se/en/what-we-do/projects/sekond2life-ecosystem-for-reuse-of-automotive-components

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Christian Jonasson

christian.jonasson@ri.se
RISE

Vincent Schaller

vincent.schaller@ri.se
RISE