# Development of the State of Warranty (SOW) for Electric Vehicles

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RED CERVERA – TRANSICIÓN ENERGÉTICA

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# Context

The sales of electric vehicles is increasing steadily a 40% each year

An inappropriate management of the warranty could lead to:

- Systematic replacement of battery systems under warranty.

Maintenance schedules of electric vehicles are complex.

- The maintenance activities of critical components are done in a preventive or predictive way.
- The maintenance activities of non-critical components are done in a reactive way.

# Proposal

A new qualitative meta-state: the **State Of Warranty** (SOW).

Scope: the battery system.

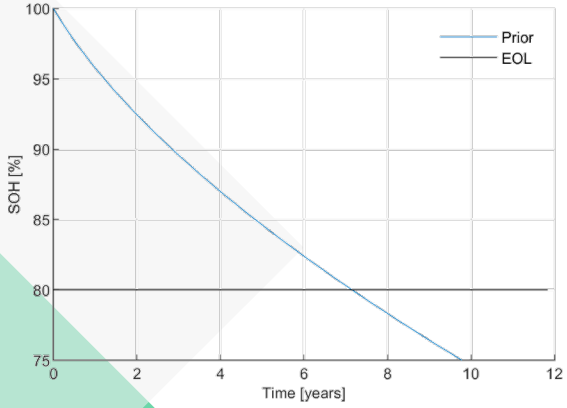
- It synthesizes the most relevant quantitative indicators (sub-states) of each of the maintenance methodologies in one merit.
- It allows to simplify the multi-maintenance methodology into a global and unique maintenance methodology.
- It provides the milestone to develop a synthesized platform for the multi-component maintenance.

# Needs

## 1) **REACTIVE**
### The prior or expectation

The already obtained knowledge about the electric vehicle itself before it starts working.

- The aging evolution.
- The warranty definition.

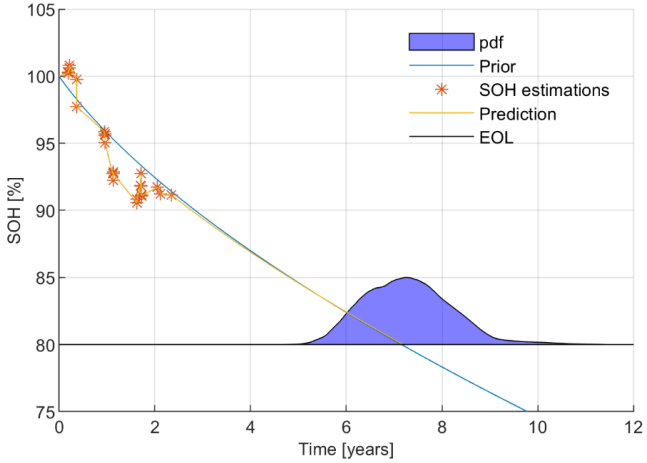



## 2) **PREVENTIVE**
### SOH estimator

The SOH is the state of a component that describes its health status.


## 3) **PREDICTIVE**
### RUL prognosis

The time [years] or kilometres the EV [battery] can still be operative



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# 1) **REACTIVE**
## Remaining warranty (RW)

Provide information about the closeness of the end of the stated warranty.

We propose 4 events of interest:

1) The beginning of warranty.
2) 5% of the total warranty remain available (advice).
3) 1% of the total warranty remain available (alarm).
4) The end of warranty.

**Implementation**:
A first order linear equation for the range 0 to 1.

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## 2) **PREVENTIVE**
## Remaining health (RH)

This state has two objectives:

- Contextualized the SOH estimation to ease its interpretation.
- Show the closeness to the appearance of a sudden failure (in this study, the EOL).

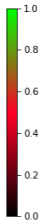
We propose 3 events of interest:

1) The estimated SOH is equal or higher than the expected one at the present instant.
2) The SOH value that defines the EOL plus 3%.
3) The EOL.

**Implementation**:
Two piecewise-defined function built with first order linear equations for the range 0 to 1.

$$\mathrm{SOH}_{expected\ k} > \mathrm{SOH}_{\mathrm{event2}}$$

$$\mathrm{RH}_k = \begin{cases} 1 & \mathrm{SOH_k} > \mathrm{SOH}_{expected\ k} \\ a_1 + \Delta\mathrm{SOH}_{1\,k} \cdot b_1 & \mathrm{SOH}_{\mathrm{event2}} > \mathrm{SOH_k} \geq \mathrm{SOH}_{expected\ k} \\ a_2 + \Delta\mathrm{SOH}_{2\,k} \cdot b_2 & \mathrm{EOL} > \mathrm{SOH_k} \geq \mathrm{SOH}_{\mathrm{event2}} \\ 0 & \mathrm{SOH_k} < \mathrm{EOL} \end{cases}$$




$$\mathrm{SOH}_{expected\ k} < \mathrm{SOH}_{\mathrm{event2}}$$

$$\mathrm{RH}_k = \begin{cases} 1 & \mathrm{SOH_k} > \mathrm{SOH}_{expected\ k} \\ a_3 + \Delta\mathrm{SOH}_{3\,k} \cdot b_3 & \mathrm{EOL} > \mathrm{SOH_k} \geq \mathrm{SOH}_{expected\ k} \\ 0 & \mathrm{SOH_k} < \mathrm{EOL} \end{cases}$$

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## 3) **PREDICTIVE**
## Remaining useful warranty (RUW)

Inform the vehicle manufacturer about the warranty state way before its non-fulfilment

We propose 4 events of interest:

1) The theoretical remaining useful life based on the expectations.

2) The RUL defined on the warranty.

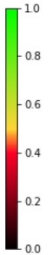
3) The non-compliance of the warranty in 80% of the defined warranty period.

4) The non-compliance of the warranty in half of the defined warranty period (+2 replacements).

**Implementation**:

A piecewise-defined function built with first order linear equations for the range 0 to 1.

$$\mathrm{RUW}_k = \begin{cases} 1 & \mathrm{lifespan_k} > \mathrm{lifespan_{event1}} \\ a_1 + \mathrm{lifespan_k} \cdot b_1 & \mathrm{lifespan_{event1}} > \mathrm{lifespan_k} \geq \mathrm{lifespan_{event2}} \\ a_2 + \mathrm{lifespan_k} \cdot b_2 & \mathrm{lifespan_{event2}} > \mathrm{lifespan_k} \geq \mathrm{lifespan_{event4}} \\ 0 & \mathrm{lifespan_k} < \mathrm{lifespan_{event4}} \end{cases}$$

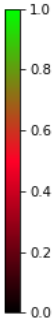


# SOW

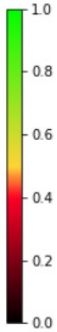
## QUANTITATIVE

1) REACTIVE


2) PREVENTIVE




3) PREDICTIVE

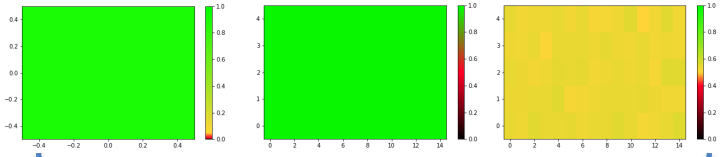


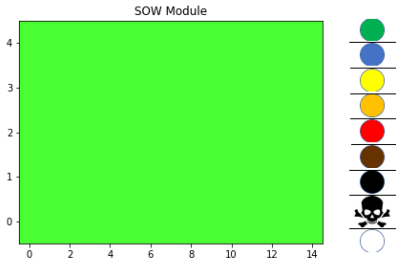

## QUALITATIVE

| SOW | RW | RH | RUW | Severity Description |
|---|---|---|---|---|
| | >0.05 | >0.75 | >0.5 | The warranty fulfilment level is correct. |
| | <0.05 | >0.75 | >0.5 | The warranty fulfilment level is correct, but the end of warranty is close. |
| | - | >0.75 | 0.5> RUW >0.4 | **ATTENTION**! Predicted 1 additional replacement. Early advice. |
| | - | 0.75>RH>0.5 | 0.5> RUW >0.4 | **ATTENTION**! Predicted 1 additional replacement. Middle advice. |
| | - | 0.75>RH>0.5 | 0.4> RUW >0 | **ATTENTION**! Predicted 1 additional replacement. Late advice. |
| | - | 0.5>RH>0 | 0.4> RUW >0 | **DANGER**! Predicted 1 additional replacement. Irreversible damages. |
| | - | - | 0 | **DANGER**! Predicted 2 additional replacement. |
| | - | 0 | - | **DEATH**! The battery has reached the EOL. |
| | ¿? | ¿? | ¿? | **Undefined scenario.** Something unexpected is happening. |

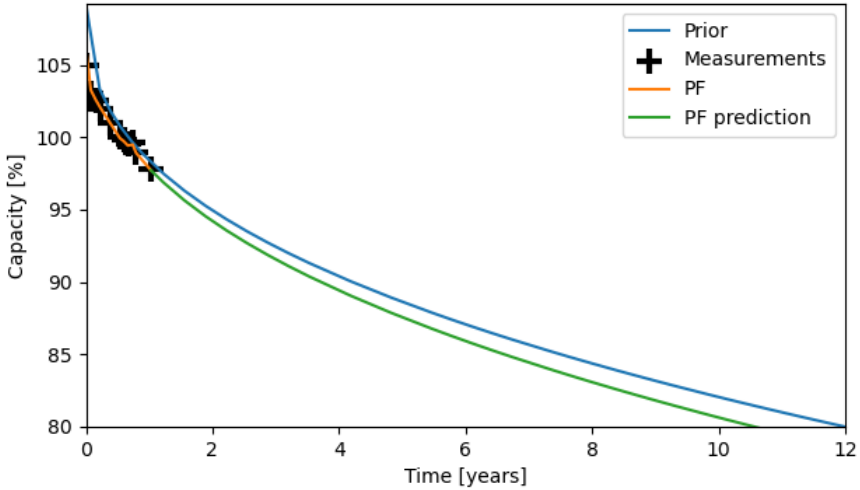
# Results

1) REACTIVE 2) PREVENTIVE 3) PREDICTIVE

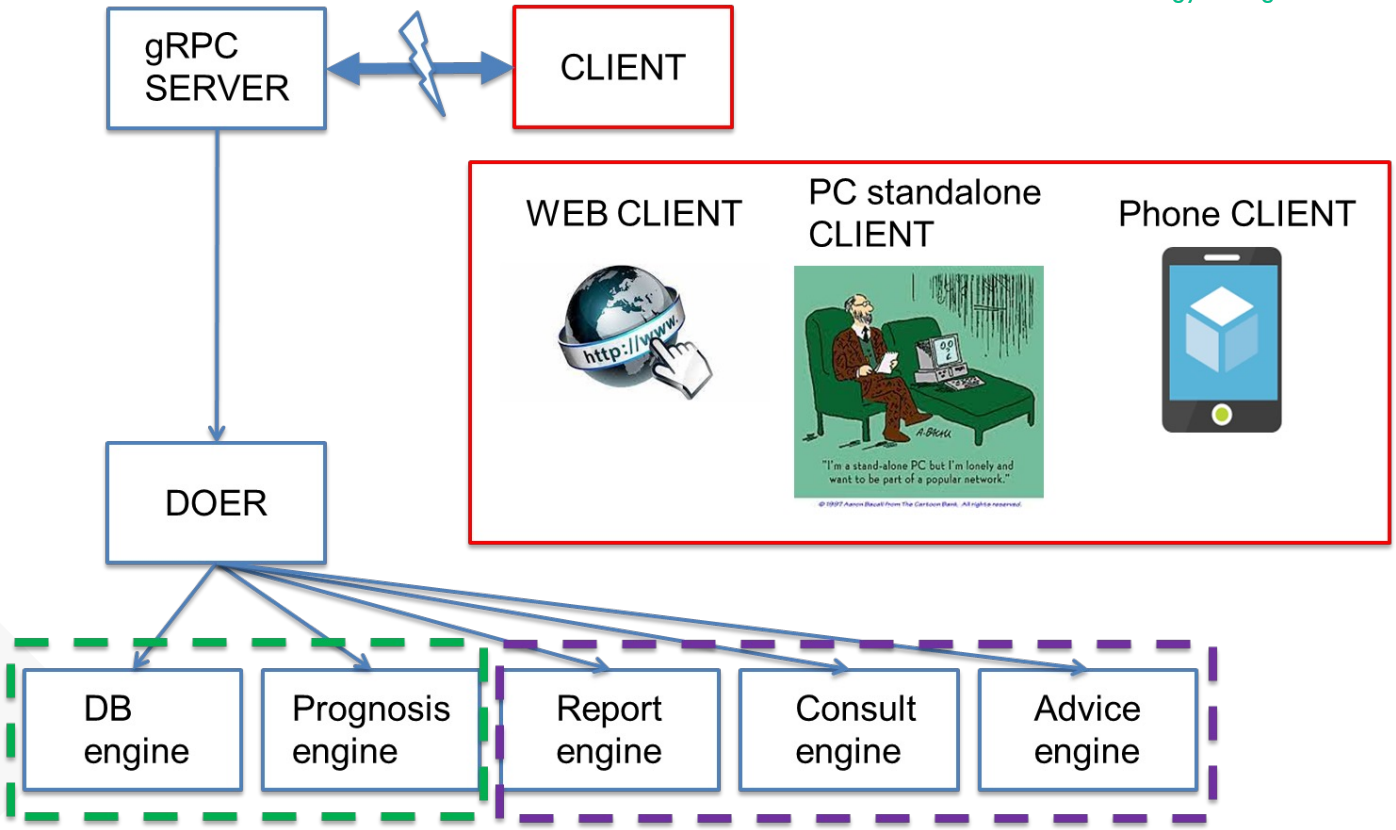





## PROGNOSIS



# Execution & exploitation




Thank you - Eskerrik asko - Muchas gracias

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