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Deliverable D2.2

Report on Standard and Regulations

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1. Executive Summary

The main objective of the LOCATE project is to replace, when it decreases the cost or improves the reliability, availability or maintainability of locomotives at a constant or lower level of risk, the preventive conditional and scheduled maintenance of mechanical parts of the bogie by predictive maintenance in order to:

- Ensure safety by having parts of the subsystem under continuous surveillance, thereby replacing planned inspections.
- Increase the availability of the locomotives by avoiding unnecessary controls or inspections done by the driver or the maintenance team performing, such as:
    - Light maintenance controls between 2 commercial trains
    - Heavier annual inspections
    - Replacement of subsystems in good health which are safe for continued operation.
- Reduce the number of unforeseen defects/incidents to increase reliability.
- Schedule interventions before the problem influences operations by identifying the warning signs of failures (data) and the corresponding degradation rates;
- Consider the constraints of the:
    - drivers
    - fleet management
    - workshop management
    - people in the workshop
- Keep under control the interfaces with the infrastructure

The following tools and methodologies will be implemented:

- Identifying faulty components by means of vibration analysis based on data collected with sensors fitted to bogie sub-systems. The data collected is then processed in order to make possible reliable maintenance decisions (time before withdrawal from service and conditions for return to operation)
- Supporting maintenance scheduling and integrating maintenance operations tasks into daily services, while ensuring appropriate inventory control of stock and spare parts and assigning maintenance crew/technicians according to their skills/competences

Therefore, we shall modify the maintenance framework and intervention criteria for the demonstrator locomotive. Proof must be provided that the safety level is preserved or improved. We will make use of established methods, where possible, already used by several railway operators inside Europe as proposed when implementing the Entities in Charge of Maintenance.

According to the European and local rules “trains must be operated safely” [EU Document 2019/799] by their Entities in Charge of Maintenance. As FGC operate and maintain this local network, this directive shall not apply to FGC. But applying thee principles and methods contained within the directive should be considered by the Spanish NSA as best-practice. A risk assessment must be done in order to prove that the level of RAMS (Reliability, Availability, Maintainability and Safety) is better than that achieved today (lower Risk Priority Number). The costs must be lower than today: to be demonstrated by a Life Cycle Cost (LCC) impact calculation. We will, therefore, use the methods described in in the following standards:

EN 50126-1 and 50126-2 Railway Applications. The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)More precise advices will be used in the following UIC documents drafts

IRS 80880-1 Railway applications: Reliability, availability, maintainability and safety – Guide to the implementation of EN 50126 to mechanical components of railway vehicles IRS 80880-2 Railway applications: Guideline for the application of Life Cycle Cost analysis to railway vehicles

EN 17023 - Railway applications — Railway vehicle maintenance — Creation and modification of a maintenance plan

In addition to standards related to the development and modification of a maintenance plan defined above; subsequent work packages will also need to consider specific standards and regulations related to the development of the condition monitoring system and its interaction with other systems on the locomotive and in the depot. For example; ISO 13374 ‘Condition monitoring and diagnostics of machines — Data processing, communication and presentation’ provides the basic software requirements for condition monitoring and diagnostics systems, ISO 17359 ‘Condition monitoring and diagnostics of machines’ - which includes a generic procedure to be used when implementing a condition monitoring programme.

2. Abbreviations and acronyms

Abbreviation / Acronyms	Description
ECM	Entity in charge of maintenance
FMECA	Failure Modes, Effects and Criticality Analysis
FMM	Fleet Maintenance Management Function
LCC	Life Cycle Cost
MDL	Maintenance Delivery Function
MDV	Maintenance Development Function
NSA	National Security Agency
RAMS	Reliability, Availability, Maintainability and Safety
RPN	Risk Priority number, level of risk

3. Background

The present document constitutes the Deliverable D2.2 “Standards and Regulation Constraints” as part of the WP2 – Requirements and Specifications.

It does not contribute to any TD/WA.

4. Objective/Aim

FGC (FERROCARRILS DE LA GENERALITAT DE CATALUNYA), being a local railway undertaker, is not mandated to be organised as an ECM as defined in the European Regulations (see 2016/798 Article 2 § 2.c). however, we propose to use these principles and methods to assess the level of safety after modification of the maintenance scheme. This should be considered as the best practice in Europe and allow the outputs of LOCATE to be applicable to other operators/maintainers.

In this Work Package we shall prove that the predictive maintenance of the bogies of the freight locomotives of FGC as imagined in this project by means of vibration measurements and calculations using a numerical digital twin, shall help FGC to:

- Improve the total level of reliability, Availability, safety and maintainability
- Decrease the costs.

This assessment will be done according to the current best-practice in the railways. The standards commonly used are those described in the EN50126-1 for the RAMS and FMECA calculations and the EN50126-2 for the life cycle cost calculations.

The following situations will be compared

The current situation after 30 years of operation and return of experience	The new situation with predictive maintenance based on data to be collected and analysed
- scheduled systematic maintenance with a fixed organisation and known level of work in the ??? and - troubleshooting operations. Not predicted, very difficult to be organised due to variability in the weekly volume of work on the shop floor.	- Most of the maintenance work will depend on the condition of the fleet and will therefore result in - adapted work planning requiring powerful tools - a greater need for expertise in interventions, with simple inspection work being partly replaced by vehicle measurements and numerical simulations.

The assessment of the measuring tools and the data processing system will be done by comparing the failures identified during conventional maintenance operations done “as usual”, that will be retained during the transitional period, with the forecasts of the system set up for predictive maintenance.

During this period the speed of evolution of the anomalies

- highlighted during data processing

- into defects detectable during inspections or resulting in incidents in operation will continue and the corresponding models will be improved.

This will be an opportunity to show the workshop teams that their know-how will continue to be essential in order to always adapt maintenance to the condition of the fleet.

The different ECM functions as described in the European Regulations will be adapted according to the new way of organising the maintenance.

5. Organisation of FGC acting as an ECM

Annex II of the document 2019/779 [2] describes the 4 functions of an ECM. We will examine them further on in this document.

5.1. The management function

The management function:

- Adopts a maintenance policy according to the organisation and the type of services provided
- Defines safety targets; puts in place the control or audit processes enabling the ECM to position itself in relation to its objectives;
- Organises the risk assessment with all the stakeholders and the available tools and puts in place the necessary measures;
- Organises the controls, audits to be sure that these measures are applied and effective.

The maintenance targets must be clearly identified (the bogie with all its components in this project) in the breakdown structure to be identified (definition documents of FGC).

We must define this target in the risk assessment process as described in 80880-1 with FGC for each part considering

1. Availability: A measure of the degree to which an item is in the operable and committable state at the start of a mission when the mission is called for an unknown (random) time; maximum time a locomotive is not operated due to failures and repairs
2. Reliability: The probability an item will perform its intended functions for a specified period under stated conditions; number of incidents each period or distance travelled
3. Maintainability: The probability an item will conform to specified conditions within a given period when corrective or preventive action is performed; mean time to repair
4. Safety: the probability that a system will either perform its functions correctly or will discontinue its functions in a manner that does not disrupt the operation of other systems or compromise the safety of any people associated directly or indirectly with the system; events that may impact safety.

5.2. The maintenance development function (MDV)

The aim of this function is the management of the maintenance file. In this file(s) you find:

- The configuration of the locomotives;
- The changes in operation (mileage, tonnage, parts of the network used, modification of the signalling, …): Their impact on the behaviour of the locomotive Return of Experience;
- The today maintenance plan, the changes made in the past and their impact;

- Availability of spare parts changes due to obsolescence. Ongoing problems due to obsolescence. The locomotives were design during the 80ies;
- Incidents, accidents or defects occurred during operation. Data from the drivers, the workshop linked to them. Are there statistics? Analyses after accidents?
- Is there technological survey in order to avoid obsolescence? Are there problems of this type on the subsystem taken into account in the LOCATE project?
- This function identifies the parts linked to safety (see Article 4 of [2]. The list of parts will be checked before the risk analysis. We will make a FMECA analysis. We will take into account the return of experience gathered by FGC during the operation;
- have also be considered the near misses identified by the operation staff, the drivers or the maintenance staff, such as abnormal under-body shocks due to bogie movements reported by drivers, significant impacts on bogie stops caused by sudden bogie strike movements;

In this case the events against safety could be

- Derailments: specific zone of the lines? In relation with the wheel profile? Damper condition?
- Exceeding braking distances due to brake execution equipment;
- Hot axle boxes: are there sensors along the track? Is there a database? Are the measurement results usable for locomotive maintenance? How fast do the temperatures of each axle box evolve over time? Or shall we provide the locomotives with specific sensors?
- Cracks in wheels: types and amounts of cricks, mileage from reprofiling to crack detection? Speed of evolution?
- Dismantled dumpers: Dismantled mechanical assemblies;
- …

5.3. Fleet maintenance management (FMM)

The aim of this function is to organise the removal and the return to operation before and after maintenance. This function has contacts with entities inside and outside the ECM. Availability simulation must be done according to 80880 1 and 2.

- What are the actual maintenance steps compared to the theoretical maximum steps? How is the planning of the inspections made? Is it possible to use the maximum steps? e.g. what is the maximum step between 2 successive axle inspections? What is the average step found?
- What are the main operational constraints? Availability? How many locomotives in operation are needed? How many locomotives can be stopped for maintenance? When? Day night weekend, working day?
- When are those trains operated? What would the customer like? Day, night? When are the maintenance tasks performed? Is the availability always the same? All day long? Seven days a week?

- Are there locomotives operated in degraded modes with speed or tonnage limits?
- Are there any spare parts shortages?
- Who decides if a locomotive can go back to operation? Are there criteria? Discussed with the MDV function?
- Who decides to stop a locomotive for planned maintenance? For corrective maintenance?

5.4. Maintenance delivery function (FDL)

The aim of this function is the technical making of the ordered maintenance task.

- What are the skills? How are they identified?
- What are the existing records of this function? How are they linked to the return of service in operation?
- What are the links and procedures with the other functions?
- Is numerical data used by the operators?
- Quality management of the work that is done. How is it organised? Are there records? all the time? In the event of an incident?
- The group of experts of the workshop
- Workshop experts must be involved in this approach as their expertise is still needed to adapt predictive maintenance to the condition and use of the fleet.

6. Conclusions

The work on the maintenance system must go one while the specialists of the project team work on the scientific methods to be used in predictive maintenance.

The assessment of the impact on the level of risk and the cost will be done:

- Considering the framework of European regulations giving the missions of an ECM
- Using the methods described in the 2 IRSs 80880-1 and 2

The reaction of FGC experts to this important paradigm shift in maintenance organisation will also need to be considered. Therefore, we are going under the control of FGC's management to involve them in this process.

7. References

In this part of the LOCATE project we use

- the principles given by
  - [1] EU Directive 2016/798 for Railway security
  - [2] EU 2019/779 certification of Entities in Charge of Maintenance
- the methods proposed by
  - [3] EN 17023 Railway applications - Railway vehicle maintenance - Creation and modification of maintenance plan and
  - [4] EN50126 Railway applications. The specification and demonstration of reliability, availability and safety (RAMS)
  - [5] Risk-Based Reliability Centered Maintenance by Marius BASSON (industrial press)
  - UIC 80880-1 and 2 giving tools to apply the principles described in EN 50126 1 et 2.