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Title:

Cost-driven and reliability-driven analyses of the Y25 bogie to identify needs and opportunities for predictive maintenance

Authors & affiliations:

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Abstract: (Your abstract must use **Normal style** and must fit in this box. Your abstract should be no longer than 1200 words. The box will 'expand' over 2 pages as you add text/diagrams into it.)

Preparation of Your Abstract

1. The title should be as brief as possible but long enough to indicate clearly the nature of the study. Capitalise the first letter of the first word ONLY (place names excluded). No full stop at the end.
2. Abstracts should state briefly and clearly the purpose, methods, results and conclusions of the work.

Introduction: Clearly state the purpose of the abstract
Methods: Describe your selection of observations or experimental subjects clearly
Results: Present your results in a logical sequence in text, tables and illustrations
Conclusions: Emphasize new and important aspects of the study and conclusions that are drawn from them

Introduction (300 words)

Condition-based maintenance (CBM) policies are becoming more and more relevant to the operation of railway rolling stock and infrastructure. With CBM, maintenance is applied when the equipment needs it, rather than when it fails or on regular intervals. In this way the downtime of the infrastructure or train is significantly reduced, savings are obtained in maintenance budgets and the availability of the assets is increased. Because of the great advantages that can be achieved through the use of CBM, efforts are nowadays directed towards an integration of the real-time operational data that holds the current condition of the equipment with the maintenance systems.
The EC funded research project INNOWAG is analysing possible ways to implement CBM policies to the operation of European freight wagons, hence with a focus on Y25 bogies. Various components and sub-systems of the freight wagon are considered in this work, based on a prioritisation driven by their significance towards maintenance costs, reliability of operation and criticality towards disruption of operation. For the most significant components, specific failure mechanisms and fault detection methods are being defined also based on the availability of condition monitoring data and of historical data regarding maintenance operation performed on two fleets of freight wagons in Europe.
As part of this work, a reliability-driven analysis and a cost-driven analysis have been performed to assess the criticality of different components in the bogie towards the aims of the project, particularly the wheelsets, braking system, suspensions.
These analyses consisted in:

- a Failure Mode and Effect Analysis (FMEA) analysis where failure modes and related failure rates for different components in the above mentioned sub-systems could be identified;
- a Life Cycle Cost (LCC) analysis that allowed to obtain the breakdown of LCC cost for the bogie into the contributions related to the various sub-systems.

This work is now forming the basis for the identification of components and sub-systems most suitable for the implementation of CBM policies and also to assess the potential impact brought by the implementation of these policies in terms of increased reliability and reduced LCCs.

Methods (300 words)

The methodology adopted in the reliability driven analysis is based on a Failure Mode and Effects Analysis (FMEA). According to the FMEA analysis, failure modes are ranked in terms of

their level of criticality based on the value of a global indicator called the Risk Priority Number (RPN). The RPN is calculated for each failure mode as the product of three distinct parameters:

Severity S: a measure of the severity of the failure's consequences, defined in a range of integer values from 1 to 10;

Detectability D: a numerical indicator (also in a range between 1 and 10) describing the probability that the considered failure is detected in an early or late stage of development;

Frequency F: a value expressing in a range from 1 to 10 the frequency of occurrence of the considered failure mode.

Hence:

$RPN=S\times D\times F$.

The data used to perform the FMEA analysis are coming from companies working in the operation of freight trains, workshops for the repair and maintenance of wagons and one company providing condition monitoring services to railway operators.

Based on these data, it was possible to estimate the failure rates associated to different failure modes of the components examined, and hence the corresponding frequency values to be used in the FMEA analysis, hence the value of Frequency F in the evaluation of the RPN. The severity index S based on the classification of failures considered by the appendixes of the General Contract of Use for Wagons (GCU) as specified in Annex 1: "Catalogue of irregularities including classification into categories for use in the Quality Management System"used in the FMEA analysis was defined was obtained from . Finally, the Detectability index D was obtained from the control criteria prescribed by the rules for maintenance of freight wagons, also established by the GCU.

Besides the Failure Mode and Effect Analysis (FMEA) analysis, an evaluation of the of the bogie Life Cycle Cost LCC was performed. The lifecycle of a physical asset begins with its acquisition and ends only when it is removed from service by being sold, converted, or disposed. The LCC is the cost incurred along the whole lifecycle of an asset considering the design, purchase, construction, operation, maintenance and decommissioning phases.

The main advantage of using an asset life cycle perspective is to consider not only the initial design and purchase cost, but also to take into account all the costs derived by the utilisation of the asset itself, until the disposal of the asset at the end of its life.

In this paper, an LCC model is proposed and applied to the Y25 bogie, the most used wagon type for commercial purposes in Europe. It is frequent in practical applications, to divide the overall asset in sub-parts, so as to be more comfortable about the cost evaluation. This way will be also followed in this study of the Y25 freight wagon. Especially the focus will be put onto the bogie part of the wagon, composed by the wheelset, the bogie frame and the braking system.

Overall, the LCC model for the application on freight wagons fitted with Y25 bogies is:

$$LCC=\text{purchasing cost}+\text{maintenance cost}+\text{hidden cost}+\text{disposal cost}$$

Figure 1 below shows a more detailed representation of the cost breakdown structure for the Y25 bogie.

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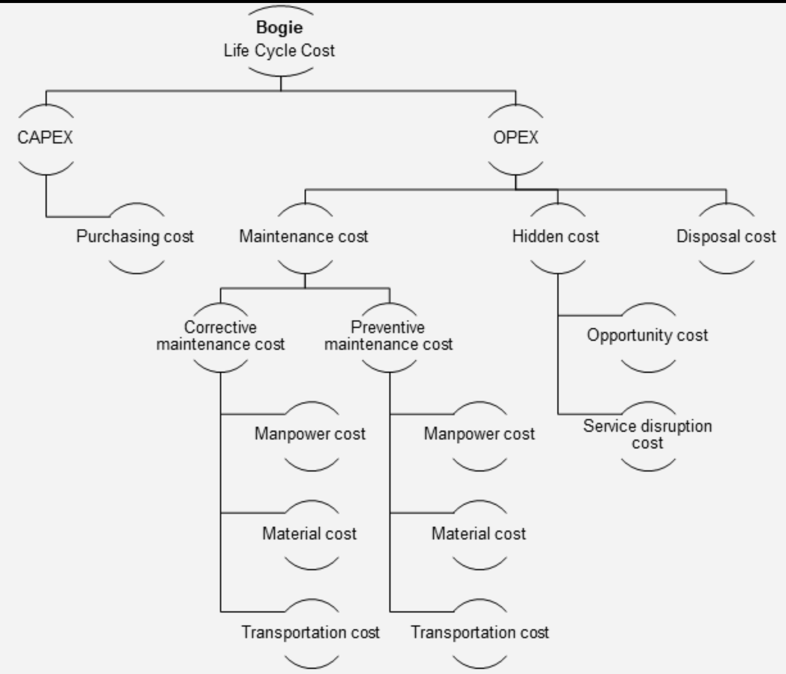

Figure 1: Cost Breakdown Structure for the Y25 bogie

Results

As an example of the results obtained, Table 1 below shows the results of the FMEA analysis for the wheelset subsystem in the bogie assembly. In terms of the total RPN number, the most critical failure modes identified are:

- wheel out-of-roundness for which RPN=336;
- wheel flat (similar to wheel out-of-roundness), for which RPN=336;
- build-up of material in the wheel, RPN=224;
- wrong tread profile (i.e. wheel in need of being reprofiled), RPN=224.

All of the above failure modes need to be considered as “in need of condition monitoring action”. The occurrence of an initial crack in the axle corresponds to a relatively low RPN because the frequency number F for this failure mode is obviously low (F=3). However, this failure mode corresponds to the maximum value of the severity index and therefore shall also be considered as “in need of condition monitoring action”.

Failure	GCU code	Nc	Ne	Failure rate	F rank	GCU class	GCU control criteria	S		D		F		RPN
axle crack	1.6.1.1	2	914	1.31E-06	4	5	VC	unsafe without warning	10	moderate	5	low: relative few failures	3	200
wheel out of round	1.3.3; 1.7.2; 1.7.2.1	23	914	6.04E-06	6	4	M; VC / VC	very high	8	very low	7	moderate: often there are failures	6	336
wheel crack	1.3.5; 1.3.6; 1.5	4	914	3.50E-07	3	4	M; VC / VC	very high	8	very low	7	low: relative few failures	3	168
Wheel: build-up	1.3.4;	3	914	1.97E-06	4	4	M	very high	8	very low	7	moderate: seldom	4	224

of material												there are failures		
wheel thermomechanical crack	1.3.5; 1.3.6; 1.5	4	914	3.50E-07	3	4	M; VC	very high	8	very low	7	low: relative few failures	3	168
wheel flat	1.3.3; 1.7.2; 1.7.2.1	23	914	6.04E-06	6	4	M	very high	8	very low	7	moderate: often there are failures	6	336
wrong tread profile	1.2.3	1	914	1.31E-06	4	4	M	very high	8	very low	7	moderate: seldom there are failures	4	224

Table 1: Results of the FMEA analysis for the wheelset

In terms of results of the LCC analysis, again taking the wheelset sub-system as an example with more results being presented in the full paper, Figure 2 shows the cumulated cash flows for the wheelset, computed over 30 years of service and Figure 3 shows in percentage terms the share of cost allocation for the wheelset.

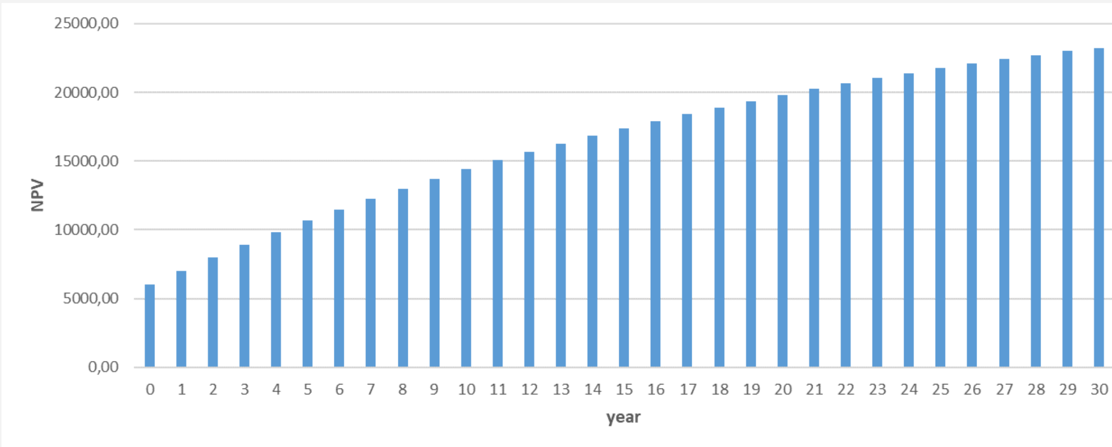

Figure 2: Cumulated cash flows for the wheelset

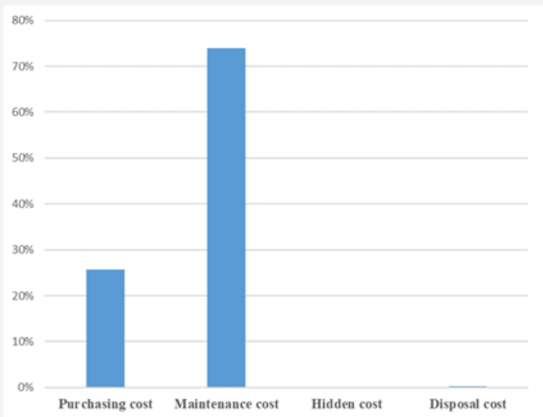

Figure 3: Cost allocation for the wheelset

Conclusions and Contributions

This abstract presents the results of reliability-driven and cost-driven analyses performed to

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achieve a prioritisation of bogie components in terms of their relevance to the implementation of predictive maintenance policies.
The results show that there is significant scope in devising predictive maintenance policies for some of the components in the bogie, in particular for the condition of wheels and axles and for the braking system.
More details providing support to this statement will be provided in the full paper, also on the basis of the illustration of some selected case studies.

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