UIC B 169/RP 43 (May 2015)

RAMS - GUIDELINE

RAMS - Guideline: Reliability, availability, maintainability, safety - Implementation of EN 50126 for Mechanical Components in Railway

Rail System Forum Rolling Stock SET 6, "Running gear".

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OF RAILWAYS

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Project

RAMS - Guideline

Contractor	Customer
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Abstract

The aim of the project is to make it possible to calculate characteristic RAMS values on the basis of EN 50126 to determine the reliability and safety of railway rolling stock running gear. The project is to draw upon the results of work by the "Joint Sector Group for the ERA Task Force on wagon/axle maintenance" (JSG), findings from the EURAXLES projects and the results of the UIC SOR project. These characteristic values are necessary to safely analyse changes in the running gear and their effects.

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The outcome will be to make it possible to calculate characteristic RAMS values. At its completion the project will have provided a procedure for determining these characteristic RAMS values, demonstrating it by means of practical calculations.

Keywords

Wheelset, Railway axles, wheels, axleboxes, Reliability, Availability, Maintainability, Safety, FMECA, RAMS, LCC

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Amendments

Amendment number	Amendment made by (in CAPITALS)	Date made (YYYY-MM-DD)

Abbreviations

CSM	Common Safety Methods
Dist	Average distance between source and destination according to the track net
EFA	External Functional Analysis
FMEA	Failure Mode Effect Analysis
FMECA	Failure Mode Effect and Criticality Analysis
IFA	Internal Functional Analysis
FTA	Fault Tree Analysis
LCC	Life Cycle Cost
LAMIS	Time needed for logistic and administrative issues for maintenance in service
LAMOV	Time needed for logistic and administrative issues for maintenance off the vehicles
MIS-DC	Time expenditure for the maintenance in service (MIS) incl. delivering and collecting the vehicle
MIS	Maintenance in service - Time needed for maintenance in service
MOV	Maintenance off vehicle - Time needed for maintenance off the vehicles
MTBF	Mean Time Between Failure
OHJ	Operation hours Journey-time

OHL	Operation hours loading / unloading
OHML	Operation hours needed for Maintenance
OHPR	Operation hours needed for Provision and Replenish
PBS	Product Breakdown Structure
RAM	Reliability, Availability, Maintainability
RAMS	Reliability, Availability, Maintainability, Safety
RPN	Risk Priority Number
RPN_L	Risk Priority Number - Limit
UIC	International Union of Railways

1. Purpose

Up to now for executing RAMS - Analysis the user was facing a huge number of methods without a common recommendation for using a suitable method instead of another to analyse his component.

This guideline was prepared in the UIC - SET 6 project “Reliability and safety of axles, wheels and axle bearings, implementation of the EN 50126” based on the examples of wheelsets and bogies. The application on the wheelset and bogie are described in UIC B 169, RP 29.

The guideline is a document showing to the user the necessary steps and how to apply the methods or tools recommended in the document. In this sense the guideline will allow the user (expert in the treated item) to perform the RAMS analyses for mechanical components by himself. It is obvious that the user will not be necessary a RAMS specialist but would have a clear idea about what to do for a RAMS analysis. For more detailed information he may consult a RAMS specialist.

To perform the RAMS analysis the project developed some tools. These tools are implemented in the following excel files:

- EFA_AFE___IFA_AFI
- FMECA_AMDEC

This document is the guideline for the correct use of these tools and the interpretation of their results.

This methodology is also applicable for other mechanical components of railway rolling stock material.

In addition to RAMS - analysis, in order to consider also economic requirements, a LCC methodology has been developed. The LCC-guideline and the LCC tools are integrated in the separated document “LCC-guideline_UIC”, including the following files:

- LCC–Calculator_UIC
- LCC-Presentation-charts_UIC.

<u>The guideline is split into two major parts</u>:

- Risk analysis - representing the “S”, safety, of RAMS (chapter 5 to 8)
- RAM - analysis (chapter 9).

2. Context

The design, product and maintenance requirements of running gear components are defined in the relevant standards or technical specifications (e.g. EN - Norms, UIC leaflet, Technical specification of the operators).

In addition to these documents, several standards exists for RAMS – analysis offering multitude methods but no real help for choosing the adequate method. Furthermore the methods are often described in a not adequate way for the not deeply involved experts. Therefore results of their applications may be improvable or not complete.

Up to now, running gear components have not been systematically subjected to safety analysis performed following the EN 50126 approach, and the associated characteristic values have not been recorded and published in quantitative terms.

The EN 50126 approach is useful to identify and assess the effects of changes (e.g. use of new materials) on reliability, availability, maintainability and safety (RAMS) of the component.

The purpose of this document is to describe the stages and the methods / tools necessary for the execution of RAMS studies consistent with EN 50126 in order to monitor the reliability / safety of running gear components on railway rolling stock.

The user shall take into account that there are various factors influencing RAMS and the operating and maintenance conditions of these components.

3. List of principal documentary references

In the following table the user will find a list of references for RAMS analysis...

Reference	Title
EN 50126	Railway applications - Specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
EN 31010	Risk management - Risk assessment techniques
EN 60812	Analysis techniques for system reliability - Procedure for failure mode and effect analysis (FMEA), 11-2006
CSM	Common Safety Methods, EC - Regulation 352/2009, Version 24.04.2009 (repealed with effect from 21 May 2015)
CSM	Common Safety Methods, EC - Regulation 402 /2013, Version 30.04.2013

Table 1 - List of principal documentary references for RAMS analysis (March 2014)

4. The Risk Analysis process

The risk analysis process shows the working steps to execute the safety part ("S") of RAMS. In the flowchart below (Figure 1) the process is visualized for risk analysis. Each stage in the flowchart is detailed in the paragraphs hereafter.

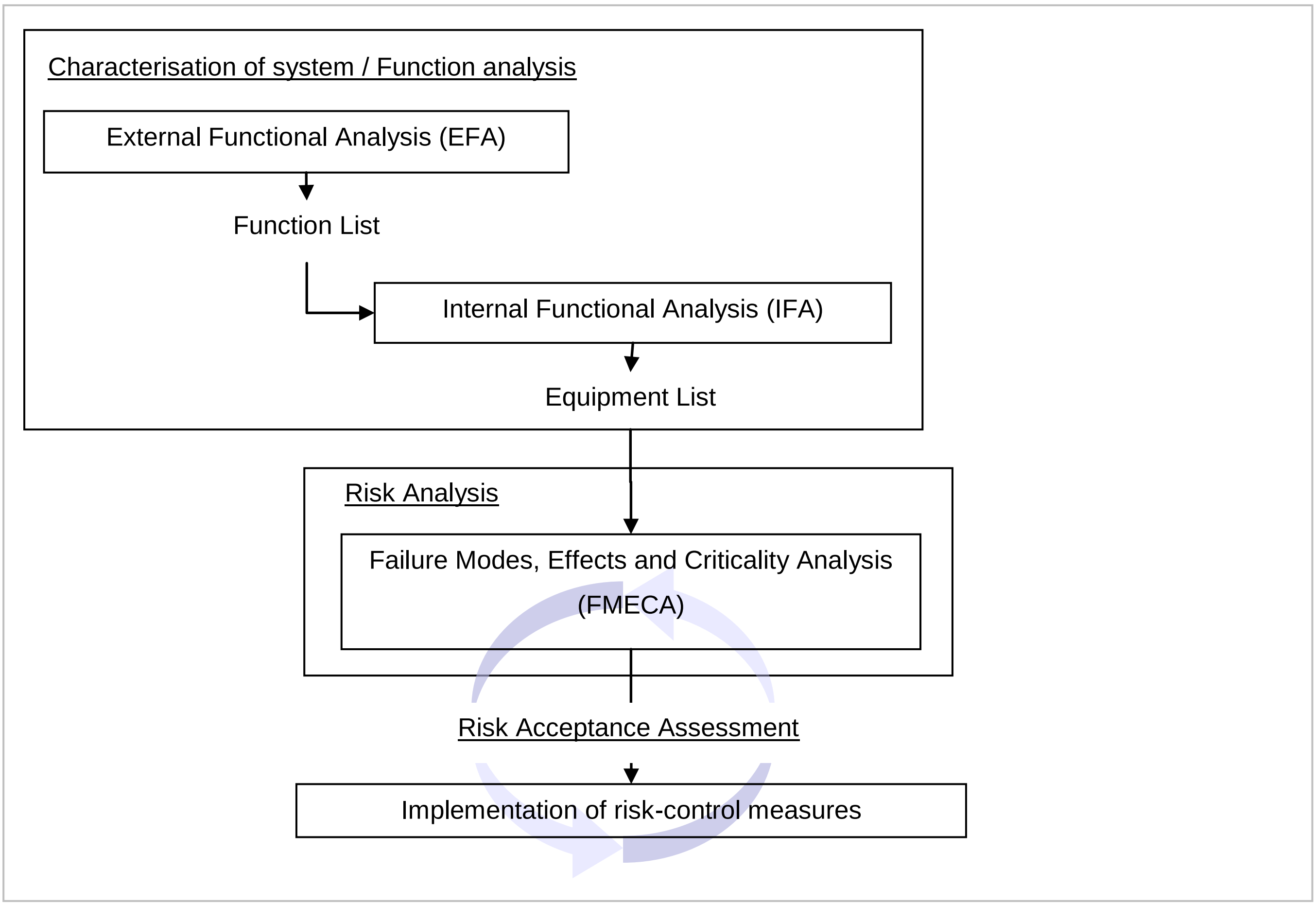


Figure 1: Structure of the risk analysis process

The risk analysis can be done in each of the 14 life cycle phases of the object, according to EN 50126, e.g. the design phase, the development phase, the production phase as well as the operation phase.

The project has focussed its activities mainly to the "operation and maintenance" phase.

5. Characterisation of the system / Functional analysis

The purpose of the functional analysis is to characterise a system by its functions, the environment, operational conditions and its elements (components).

The functional analysis will be done by two separate analyses: first the external functional analysis (EFA) and then the internal functional analysis (IFA).

5.1. External Functional Analysis (EFA)

With the external functional analysis the system boundaries as well as the external influences on the system are identified.

The external functional analysis (EFA) is to be performed at the start of the project in order to ensure that there is a comprehensive list of the functions to be met.

5.1.1. Purpose

Describing the system boundaries and the interfaces, the focus is set only on the regarded system like a spotlight in a theatre.

Aspects of the external functional analysis (EFA) are the intended use, the intended functions, the environment conditions as well as existing safety measures.

Finally everybody will have a clear idea about the life cycle phases, for which purpose and under which circumstances the regarded system is due to be operated.

The EFA's purpose is to:

- identify all functions of the system under consideration, e.g. the wheelset,
- identify all constraints the system must be subjected to,
- characterise the environment in which the system operates,
- characterise the interfaces with the environment in which the system operates.

Note that possible or planned technical solutions are not to be included in this analysis. It is therefore better not to focus on specified components, but rather to consider the regarded system (e.g. wheelset) as a "black box" which represents the system to be analysed.

5.1.2. Methodology

In order to simplify the work to be done by the user a standard format was elaborated, based on MS Excel. The user shall insert inputs in the light blue cells.

Elements of the external functional analysis are as following:

- System name
- Regarded life cycle phases according to EN 50126 [Version 2000/03]

- Designated use of the system
- Functions of the system (primary and secondary)
- System constraints (physical and functional)
- Interfaces (physical and functional)
- System environment
- Existing safety procedures
- Assumptions which determine the bounds of the risk assessment.

The parts constituting the external environment represent the surroundings in which the system operates.

These external elements can be other parts of the rolling stock (including axle loads) or parts that do not belong to the rolling stock (e.g. rails).

The principal functions identify the relationships that the system establishes between two or more external parts. They express the functions performed by the system within this relationship.

The constraint functions identify the constraints imposed on the system by some constituent parts of the external environment.

As an example the EFA of the wheelset was elaborated in the UIC project "Reliability / safety of axles, wheels and axle boxes, implementation of EN 50126" and is shown in the MS Excel-file "EFA_AFE___IFA_AFI.xls".

5.2. Internal Functional Analysis (IFA)

The internal functional analysis producing the product breakdown structure of the system (PBS), as shown in the MS Excel file "EFA_AFE___IFA_AFI.xls".

5.2.1. Purpose

With the Internal Functional Analysis (IFA) the system is subdivided in its components. The result is a structured equipment list, which gives an overview of the full system.

The system as whole or the single components allows to fulfil the functions identified in the External Functional Analysis (EFA) (see 5.1). This list of components (structured equipment list, PBS) will serve as structure to input the data for the Failure Modes, Effects and Criticality Analysis (see 6.1).

5.2.2. Methodology

The system will be systematically subdivided into sub-systems / components according to the Top-Down approach like a tree expanding its branches. The number of levels to be distinguished is a decision by the user according to the complexity of the system.

Usually, level 1 represents the highest level of the system definition. 2 or 3 levels are sufficient in most cases to identify a component.

The user might use the MS Excel - file “EFA_AFE__IFA_AFI.xls”, provided in this guideline. In sheet “IFA” an appropriate format is offered. The user will refer to the Product Breakdown Structure (PBS), presented in the file “EFA_AFE__IFA_AFI.xls”. The PBS defined in the file EFA_AFE__IFA_AFI.xls for wheelsets has been used as base to develop the failures in FMECA – Excel file, as it can be seen in the example for wheelsets of the UIC project.

The IFA_AFI in the MS Excel-file (see Appendix 1) is one input for the FMECA and for LCC.

As an example the IFA the wheelset was elaborated in the UIC project “Reliability / safety of axles, wheels and axle boxes, implementation of EN 50126” and is shown in the MS Excel-file “EFA_AFE___IFA_AFI__Radsatz_Essieu_Wheelset.xls” (see Appendix 2).

Important hint for the special case of the wheel set axle:

– The axle is one single component but with different areas which offer different types of potential failures. Because of that it was decided to split the axle into 8 different areas which are handled as single components.

This procedure can also be used for other components, where it seems appropriate. This example shows the flexibility of the method.

6. Risk Analysis

This stage identifies risks, assesses their acceptability and, if necessary, determines the measures needed to achieve an acceptable risk.

For the predominantly mechanical systems like running gear or wheelset, the application of the method Failure Modes, Effects and Criticality Analysis (FMECA) is recommended and described.

Via characterisation of the system (functional analyses, EFA and IFA) and the analysis of its possible failures (FMECA), the failures will be ranked by criticality level, known as Risk Priority Number (RPN).

It was decided to perform a FMECA-type risk analysis since this is the most suitable method for a purely mechanical system.

The results of this analysis will allow the user to show that the risks relating to the possible failure of the analysed system are under control, or, otherwise highlight the function / components that need some action for improvements.

6.1. Failure Modes, Effects and Criticality Analysis (FMECA)

FMECA is a method for analysing and assessing risks. A MS Excel file “FMECA_AMDEC.xls” to determine the parameters for the analysis is attached here for general purposes. The information for the correct use of the tool is given below, explained in the wheelset example.

Note that MS Excel ask the user to accept Macros. These Macros can be accepted by the user.

Especially for wheelsets the following FMECA_AMDEC file including the list of failure definitions can be used.

6.1.1. Purpose

The purpose of the FMECA is:

- to identify comprehensively all failures of the system (identified during Internal Functional Analysis (IFA), see 6.2) and their causes;
- to identify the impacts of these failures at the various functional levels of the train and present them in a transparent and comprehensive way;
- to determine the significance, known as the "criticality", of each failure as a function of its influence on the train's normal operation or performance level, and to assess the impact of this on the train's reliability and safety;
- to calculate the Risk Priority Number (RPN) for each defined failure and mirror it at the RPN limit set by the user himself. Failures with an RPN exceeding the RPN limit indicate the highest criticality in reference to the other failures in order to identify the risk-control measures needed to render acceptable the criticality which caused the component to fail

The user is free to use other FMECA tools, but the tool embedded in this guideline is already prepared for wheelsets and wheelset components. The description of this tool is written in the in paragraphs hereafter.

6.1.2. Methodology

The Excel-file “FMECA_AMDEC__Wheelset.xls” comprises the following six sheets.

- Sheet "Example": Illustration of a failure cascade whose effect becomes the root cause for the following failure in the table which gets an own line in the FMECA - table.
- Sheet “FMECA”: In this sheet the user proceeds the assessment.
- Sheets “Severity”, “Detectability”, “Frequency” contain the range of values for the assessment of the defined failures. For comparison reasons the content of these three sheets should be untouched by the user.
- The sheet “Legend” contains explanations about the different meanings of cell colors as well as some range of values for choice box cells.

Starting a new assessment the user opens the sheet “FMECA".

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Component:	Güterwagenradsatz klotzgebremst mit ORE Rad, 22,5 t Essieu de wagons à marchandises, freiné semelles avec un roue monobloc, 22,5 t							Existing System:						
2			Number of defined failures:	165					Risk Priority Number (RPN) limit for intensive proovings:						250
3	Component level I	Component level II	Component level III	Component level IV	Failure root cause A	Failure B	Direct consequence of the failure C	comments	Severity 1.: B 2.: C		Detectability 1.: B 2.: C & A		Frequency 1.: B 2.: A		Risk priority numb
46	Wheelset	Axle	Transition radius	Transition radius	unsufficient geometrical quality (quality of production	crack	possible propagation in the long term, axle could break in the corresponding								0
47	Wheelset	Axle	Transition radius	Transition radius	unsufficient quality of material (Quality of production)	crack	possible propagation in the long term, axle could break in the corresponding								0
48	Wheelset	Axle	Transition radius	Transition radius	Overloading of the wagon	crack	possible propagation in the long term, axle could break in the corresponding								0
49	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	crack	axle broken in the corresponding section	derailment								0
50	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	not reported derailment in the past	crack	possible propagation in the long term, axle could break in the corresponding								0
51	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	corrosion	crack	possible propagation in the long term, axle could break in the corresponding								0
52	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	mechanical damage (mounting / dismounting)	crack	possible propagation in the long term, axle could break in the corresponding								0
53	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	overloading of the wagon	crack	possible propagation in the long term, axle could break in the corresponding								0
54	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	Surface roughness	crack	possible propagation in the long term, axle could break in the corresponding								0
55	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	unsufficient geometrical quality (quality of production	crack	possible propagation in the long term, axle could break in the corresponding								0
56	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	unsufficient quality of material (quality of production)	crack	possible propagation in the long term, axle could break in the corresponding								0
57	Wheelset	Axle	Wheel seat (axle)	Wheel seat (axle)	overloading by dynamic effects	crack	possible propagation in the long term, axle could break in the corresponding		little	3	low	6	low: relative few failures	3	54
58	Wheelset	Axle box	Axle box	Bearing	Mounting procedure	bearing mechanical damages	hot axle box								0
59	Wheelset	Axle box	Bearing	Bearing	bearing mechanical damages	hot axle box	broken journal								0
60	Wheelset	Axle box	Bearing	Bearing	Fatigue	bearing mechanical damages	hot axle box								0
61	Wheelset	Axle box	Bearing	Bearing	Incorrect handling	bearing mechanical damages	hot axle box								0
62	Wheelset	Axle box	Bearing	Bearing	mechanical shock	bearing mechanical damages	hot axle box								0

Table 2 - Screenshot of sheet “FMECA” (input values are examples)

The format of the cells is identical in all sheets:

- Grey cells: Headline or description
- White cells: Results. As these cells contain formulas the user should not change their content.

- Light blue cells: Input cells

In this example for wheelsets, because the first eight columns are already filled, the columns contain white cells. Column “Component level IV” gets different colours to indicate clearly the different sections / parts of the wheelset.

6.1.3. Summary of the working steps for a FMECA

- In cell “B1” the user inserts the name of the system to be analysed by the FMECA
- In columns “A” to “D” the user subdivides the system in its components.
- In columns “E” to “G” the user defines the failures with their root causes and consequences for each component.
- Column “H” opens the possibility of comments.
- In cell “O2” the user sets his personal limit of the RPN.
- In column “J” for each failure type the user evaluates the severity in accordance to the sheet “Severity” by choosing a number between 1 and 10 in the check box cells of column “J”.
- In column “L” for each failure type the user evaluates the detectability in accordance to the sheet “Detectability” by choosing a number between 1 and 10 in the check box cells of column “L”.
- In column “N” for each failure type the user evaluates the frequency in accordance to the sheet “Frequency” by choosing a number between 1 and 10 in the check box cells of column “N”.

Note: The description of the RPN and its values are defined in chapter 6.1.4.5.

The RPN is the result the product of the values of three columns “J”, “L” and “N” and is given in column “O”.

For failures exceeding the self-defined RNP limit (see cell “O2”) the cell colour changes to red and indicates the user that this is a failure he shall keep an eye on. For each failure deemed unacceptable (RPN > RPN limit), risk-control measures should be taken in order to render the failure acceptable (RPN < RPN limit). The RPN limit has the task to indicate the failures having the highest RPN. Measures on the failures with a high RNP will have the highest effect on improving the system.

Comparing the RPNs of an existing system with a new system:

- To improve the system the user defines measures to reduce the risk of failures in columns “Q” (Action) and “R” (Type).
- For these new defined measures the user evaluates the severity, detectability and frequency in columns “U”, “W”, and “Y” with the new RPNs in column “Z”.

- If the new RPN (in column AA) is lower than the existing RPN it demonstrates, that the new measures improve the system.

6.1.4. Detailed definition of the content of the FMECA sheet

6.1.4.1. Identification of component analysed

Component level I	Component level II	Component level III	Component level IV
Wheelset	Axle	Abutment (axle)	Abutment (axle)

Table 3 - Component breakdown

The column "Component level I" identifies the component on which the analysis will focus.

Level 1 represents the highest level of system definition, while level 4 represents the lowest. Often 2 or 3 levels may be sufficient to identify a component.

In the example above, only 3 levels are needed to identify the component. Level 4 might be important for more complex systems.

6.1.4.2. Identification of failure modes and its root causes

Component level I	Component level II	Component level III	Component level IV	1 Failure root cause A	2 Failure B
Wheelset	Axle	Abutment (axle)	Abutment (axle)	corrosion	crack
Wheelset	Axle	Abutment (axle)	Abutment (axle)	mechanical damage	crack

Table 4 - Failure root cause and failure

It is possible that a single failure is generated by various root causes. In this case, for each root cause of this failure a separate line must be added in order to determine its criticality.

In the example above, the cracks may be generated by 2 root causes (corrosion and a mechanical impact), two lines are therefore defined for the risk assessment.

6.1.4.3. Identification of direct consequences of failure mode

Component level I	Component level II	Component level III	Component level IV	1 Failure root cause A	2 Failure B	3 Direct consequence of the failure C	comments
Wheelset	Axle	Abutment (axle)	Abutment (axle)	corrosion	crack	possible propagation in the long term, axle could break in the corresponding section	
Wheelset	Axle	Abutment (axle)	Abutment (axle)	mechanical damage	crack	possible propagation in the long term, axle could break in the corresponding section	

Table 5 - Direct consequence of a failure

The "Direct consequence of the failure" columns identify the impact of the failure analysed. The column “Comments” provide the opportunity to give more information to understand the “Direct consequence of the failure”.

It is possible that a failure has no direct and/or visible impact. However, factors such as “time” or “the component's deterioration” may be considered in the "Direct consequence of the failure" column, in order to identify a consequence.

In the example above, it is noted that a crack will, in the long term, lead to the breakage of the axle.

6.1.4.4. Sequence of failures and their effects

Definition of “Failure Mode” according to the EN 50126, paragraph 3.13: "The predicted or observed results of a failure cause on a stated item in relation to the operating conditions at the time of the failure".

That means that the component is no more available for the function or, equivalently, no more able to afford "the operating conditions" it stands for. Consequently, in agreement with this definition, a degradation in the QUALITY of the component is not a FAILURE.

But the approach followed for mechanical components in this guideline is different. In order to give an evaluation of the RPN (Risk Priority Number) for each of the different degraded conditions of the component, the Effects Analysis is developed also for degraded conditions of the quality of the component with the same approach \ procedure as for the REAL failures (in the basic sense of this term in EN 50126).

In this sense, this project identified and analysed a number of failure modes which, due to deterioration over time, become failure causes for more serious failures. This means that in the FMECA some events analysed as a failure become failure root cause for other following failure modes (see following failure cascade).

Component level I	Component level II	Component level III	Component level IV	Failure root cause	Failure	Direct consequence of the failure	Comments
Wheelset	Axle	Rim	-	Too high breaking force	Flat	Damaged bearing	

Component level I	Component level II	Component level III	Component level IV
Wheelset	Axle	Bearing	-

Failure root cause	Failure	Direct consequence of the failure	Comments
Flat	Damaged bearing	Hot axle Box	

Component level I	Component level II	Component level III	Component level IV
Wheelset	Axle	Axle Box	-

Failure root cause	Failure	Direct consequence of the failure	Comments
Damaged bearing	Hot axle Box	Initial crack in abutment	

Component level I	Component level II	Component level III	Component level IV
Wheelset	Axle	Abutment	-

Failure root cause	Failure	Direct consequence of the failure	Comments
Hot axle Box	Initial crack in abutment	Crack in abutment	

Component level I	Component level II	Component level III	Component level IV	Failure root cause	Failure	Direct consequence of the failure	Comments
Wheelset	Axle	Rim	-	Too high breaking force	Flat	Damaged bearing	
Wheelset	Axle	Bearing	-	Flat	Damaged bearing	Hot axle Box	
Wheelset	Axle	Axle Box	-	Damaged bearing	Hot axle Box	Initial crack in abutment	
Wheelset	Axle	Abutment	-	Hot axle Box	Initial crack in abutment	Crack in abutment	

Table 6 - Example of the failure cascade

6.1.4.5. Criticality level allocated by RPN (Risk Priority Number)

A Risk Priority Number (RPN) is to be calculated for each line of the analysis. This enables the characterisation of the criticality level for the failure analysed (relevance of the impacts of the regarded failure).

The RPN is calculated as the product of the following 3 parameters:

- Severity **S**
- Detectability **D**
- Frequency **F**

RPN = S x D x F

The definitions of the individual levels of these 3 parameters can be found into the three sheets "Severity", "Detectability", "Frequency", and in the Appendix 3 of this document.

Component level IV	1 Failure root cause A	2 Failure B	3 Direct consequence of the failure C	Severity B		Detectability B		Frequency B	
Abutment (axle)	mechanical damage	crack	possible propagation in the long term, axle could break in the corresponding section	little	3	moderate	5	low: relative few failures	3
Bearing	Fatigue	bearing mechanical damages	hot axle box	little	3	low	6	very low: relative very few failures	2
Axlebox body (including rear and front cover)	not reported derailment in the past	mechanical damages	broken housing	little	3	low	6	little - failure is inplausible	1
Rim	exceeding brake energy input (e.g. misuse of park brake / brake incidente)	exceeding internal stress	crack	very low	4	little	8	low: relative few failures	3

Table 7 - Example of the calculation of RPN for four separate failures (input values are examples)

The assessment of failures based on these 3 parameters is carried out by the following procedure:

a) Evaluation of Severity:

The evaluation of the Severity should be assessed in the following descending order:

- First of all, the level of Severity assessed based on the content of column “Failure”.
- Secondly, to make a difference for Severity between 2 lines having different consequences, the column “Direct consequence of the failure” should be used.
- Moreover, if the failure root cause (column “Failure root cause”) gives complementary information, it should also be taken into account to define the severity.

b) Evaluation of Detectability:

The evaluation of the Detectability should be assessed in the following descending order:

- First of all, the level of Detectability is assessed based on the content of column “Failure”.
- Secondly, the detection of failure root cause (column “Failure root cause”) and the detection of direct consequences of the failure (column “Direct consequence of the failure”) have to be taken into account.

c) Evaluation of Frequency:

- The evaluation of the Frequency is done by assessement the column “Failure”.
- Secondly, the failure root cause (column “Failure root cause”) has to be taken into account.

This approach is suggested inside the tool in the headline (line 3) of the MS Excel file “FMECA_AMDEC.xls” by marking the letters A, B, and C.

The evaluation of each single parameter above can be based on qualitative (e.g. expert evaluation) or quantitative values, if available; the different approaches do not change the meaning of the resulting RPN - value.

For wheelsets, the failure definitions are already predefined by the UIC project “Reliability / Safety of axles, wheels and axle boxes, implementation of EN 50126”, see file “FMECA_AMDEC__Wheelset.xls”.

For other components the user has to define the possible failures before starting the assessment.

6.1.4.6. Identification of RPN - limit

The choice of the RPN limit “RPN_L” has no relevance for the assessment process. It can be set by the user individually. The purpose consists exclusively in identifying visually these failures having the highest RPN as a basis for potential and target-oriented improvement measures. As a consequence, the results give the user not an absolute value, but a relative value in comparison to the other failure modes analyzed.

The effect of this limit is only to focus on the most important failures. It should not be considered as a threshold.

The process adopted to identify an appropriate RPN_L for the purpose of the UIC project “Reliability/safety of axles, wheels and axle boxes, implementation of EN 50126” is described in the project report UIC B 169/RP 29, where the **RPN_L** was set at 250.

7. Risk acceptance assessment and improvement measures

7.1. General

Failures having a RPN higher than the self-defined RPN_L are defined as “unaccepted” without regarding the consequences following the failure. Measures to reduce the RPN have to be identified and assessed in the same way by calculating the RPN for the improved system.

In the artificial example below, changing supplier or the material used for the component improves the parameter “Frequency” reducing the risk criticality induced by the component's failure to an acceptable value: the RPN drops from 36 to 18.

Component level IV	1 Failure root cause A	2 Failure B	3 Direct consequence of the failure C	Severity B		Detectability B		Frequency B		Risk priority number	Action	Type	Severity B		Detectability B		Frequency B		Risk priority number
Abutment (axle)	mechanical damage	crack	possible propagation in the long term, axle could break in the corresponding section	little	3	moderate	5	low: relative few failures	3	45									0
Bearing	Fatigue	bearing mechanical damages	hot axle box	little	3	low	6	very low: relative very few failures	2	36	new bearing	quality	little	3	low	6	little - failure is inplausible	1	18
Axlebox body (including rear and front cover)	not reported derailment in the past	mechanical damages	broken housing	little	3	low	6	little - failure is inplausible	1	18									0
Rim	exceeding brake energy input (e.g. misuse of park brake / brake incidente)	exceeding internal stress	crack	very low	4	little	8	low: relative few failures	3	96									0

Table 8 - Example of the change of the RPN of a failure due to an improvement measure

Various types of action can be taken to improve the "Severity", "Frequency" and "Detectability" parameters. The main types of measure concern:

- Preventive maintenance,
- Quality,
- Design,
- Operation.

7.2. Preventive Maintenance Measures

Preventive maintenance measures may be taken in order to improve values of the "Detectability" and/or "Frequency".

Examples:

- Visual inspection or measurement of deterioration may allow an improvement in the "Detectability" parameter.
- Replacement of a used part after fixed mileage may allow an improvement in the "Frequency" parameter.

7.3. Quality Measures

A Quality-related measure may be completed in order to improve the "Frequency" (reduce the frequency of failures).

Examples:

- Quality inspections prior to the components' being mounted on train will improve the "Frequency" parameter.
- Changing the product / manufacturer may also improve the quality of a component, and thus improve the "Frequency" parameter.

7.4. Design Measures

A measure applied to the design of the component itself may be considered in order to improve the "Severity", "Frequency" or "Detectability".

Examples:

- Changing to a more reliable material may improve the "Frequency" parameter.
- Introducing a physical barrier to avoid a failure spreading may improve the "Severity" parameter.
- Introducing a defect-reporting system may improve the "Detectability" parameter.

7.5. Operating Measures

Operating rules may be designed such as to improve the "Severity" or "Detectability".

Examples:

- Check before departure may improve the "Detectability" parameter.
- Non-departure of the train in case a failure is observed may improve the "Severity" parameter.

The identified measures are described in the columns Q and R.

With the identified measures the FMECA is once more to be carried out in the columns T to Y ("New system"). The tool calculates a new RPN value for the implemented modification.

The user decides in the column AA whether the found improvement is sufficient or is not yet sufficient.

8. RAM - calculation

RAM is the shortcut for: Reliability (R), Availability (A) and Maintainability (M). The remaining Safety (S) is already treated in chapter 6 to 7.

In this chapter the calculation of RAM will be described.

The RAM calculation can be done in each of the 14 life cycle phases of the system. For new systems this is carried out mainly in the design and in the development phase, for existing systems this is carried out mainly in the production phase or in the operation phase.

8.1. General information about the calculation tool

The calculation tool is called "RAM-Calculator_UIC". It is created as an MS Excel tool.

The RAM-Calculator_UIC consists of 4 sheets for data-input.

Especially for wheelsets the following RAM-Calculator file can be used (see Appendix 5).

The format of the cells is identical in all slides:

- Grey cells: Headline or description
  White cells: Results. As these cells contain formulas the user does not change the content.
- Light blue cells: Input cells
- The content is written in three different languages: German (black), English (red) and French (blue)

In order to prevent the user from overwriting white or grey cells by mistake, all cells except the light blue ones are locked. As there is no password, the user is free to unlock these cells.

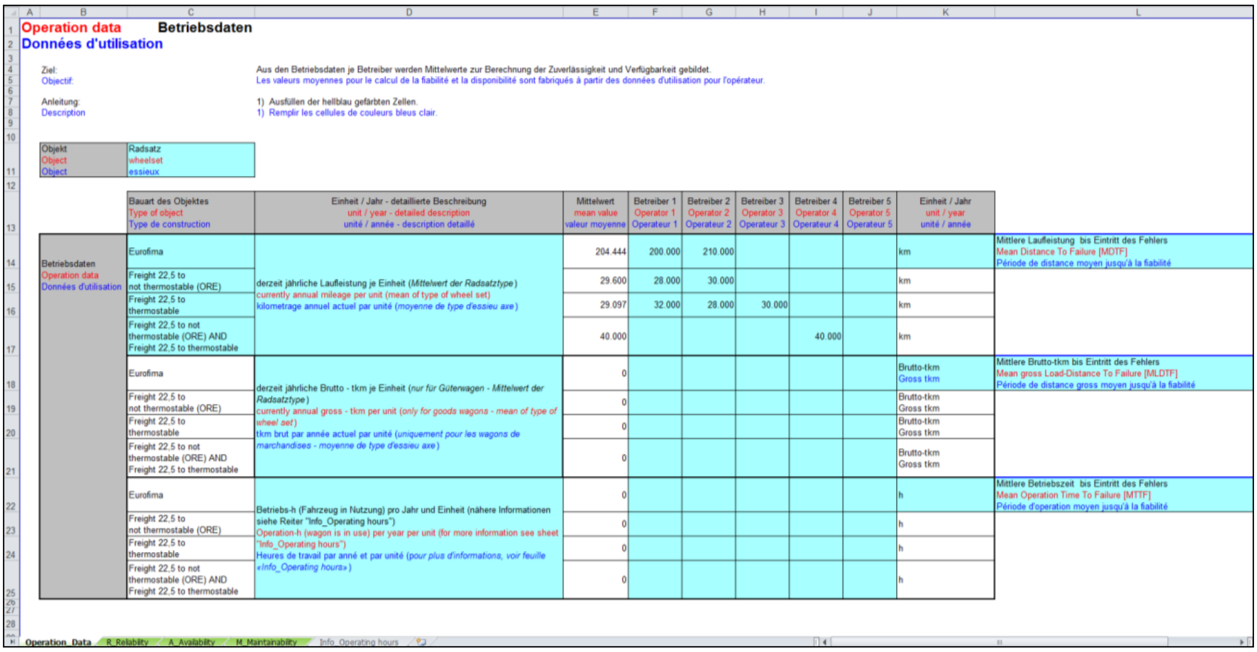
8.2. Procedure for calculating RAM with the RAM-Calculator_UIC

After opening the tool "RAM-calculator_UIC", the user starts to insert content in any of the sheets. It is recommended to start with the sheet "Operation_Data".

8.2.1. Sheet "Operation_Data"

In this sheet the user records the operation data for up to four objects (cells B14 to B17) and for the three units "km/year", "Gross-tkm/year" and "h/year".

This approach is applicable for many mechanical components of rolling stock, but for other components (e.g. toilet system) an adaptation is necessary (cells K14, K18 and 22).



Operation data Betriebsdaten
Données d'utilisation

Ziel: Aus den Betriebsdaten je Betreiber werden Mittelwerte zur Berechnung der Zuverlässigkeit und Verfügbarkeit gebildet.
Objectif: Les valeurs moyennes pour le calcul de la fiabilité et la disponibilité sont fabriqués à partir des données d'utilisation pour l'opérateur.

Anleitung: 1) Ausfüllen der hellblau gefärbten Zellen.
Description 1) Remplir les cellules de couleurs bleus clair.

Objekt / Object / Object	Radsatz / wheelset / essieux

	Bauart des Objektes / Type of object / Type de construction	Einheit / Jahr - detaillierte Beschreibung / unit / year - detailed description / unité / année - description detaillé	Mittelwert / mean value / valeur moyenne	Betreiber 1 / Operator 1 / Operateur 1	Betreiber 2 / Operator 2 / Operateur 2	Betreiber 3 / Operator 3 / Operateur 3	Betreiber 4 / Operator 4 / Operateur 4	Betreiber 5 / Operator 5 / Operateur 5	Einheit / Jahr / unit / year / unité / année	
Betriebsdaten / Operation data / Données d'utilisation	Eurofima	derzeit jährliche Laufleistung je Einheit (*Mittelwert der Radsatztype*) / currently annual mileage per unit (mean of type of wheel set) / kilometrage annuel actuel par unité (*moyenne de type d'essieu axe*)	204.444	200.000	210.000				km	Mittlere Laufleistung bis Eintritt des Fehlers / Mean Distance To Failure [MDTF] / Période de distance moyen jusqu'à la fiabilité
	Freight 22,5 to not thermostable (ORE)		29.600	28.000	30.000				km	
	Freight 22,5 to thermostable		29.097	32.000	28.000	30.000			km	
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		40.000				40.000		km	
	Eurofima	derzeit jährliche Brutto - tkm je Einheit (*nur für Güterwagen - Mittelwert der Radsatztype*) / currently annual gross - tkm per unit (*only for goods wagons - mean of type of wheel set*) / tkm brut par année actuel par unité (*uniquement pour les wagons de marchandises - moyenne de type d'essieu axe*)	0						Brutto-tkm / Gross tkm	Mittlere Brutto-tkm bis Eintritt des Fehlers / Mean gross Load-Distance To Failure [MLDTF] / Période de distance gross moyen jusqu'à la fiabilité
	Freight 22,5 to not thermostable (ORE)		0						Brutto-tkm Gross tkm	
	Freight 22,5 to thermostable		0						Brutto-tkm Gross tkm	
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		0						Brutto-tkm Gross tkm	
	Eurofima	Betriebs-h (Fahrzeug in Nutzung) pro Jahr und Einheit (nähere Informationen siehe Reiter "Info_Operating hours") / Operation-h (wagon is in use) per year per unit (for more information see sheet "Info_Operating hours") / Heures de travail par anné et par unité (*pour plus d'informations, voir feuille «Info_Operating hours»*)	0						h	Mittlere Betriebszeit bis Eintritt des Fehlers / Mean Operation Time To Failure [MTTF] / Période d'operation moyen jusqu'à la fiabilité
	Freight 22,5 to not thermostable (ORE)		0						h	
	Freight 22,5 to thermostable		0						h	
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		0						h	

Operation_Data | R_Reliability | A_Availability | M_Maintainability | Info_Operating hours

Table 9 - First Screenshot of sheet "Operation_Data" (input values are examples)

Since the recording of the operating hours can cause special difficulties, the process is explained separately in the following sub-chapter 8.2.1.1.1.

8.2.1.1. Determination of the operation hours

The determination of the operation hours is important for the calculation of the reliability (calculated on basis of one year) and for the availability. In principle, the operation hours have to be related to a unit, in this example to the wheelset.

Due to the fact that the available data acquisition systems do not measure directly the operation hours of a wheelset, a multistage procedure is applied:

a) The wheelset is mounted in a rail vehicle as a single wheelset or in a bogie.

b) A wheelset can only be used when mounted in a rail vehicle.

c) The operation hours are related to the regarded unit, e.g. the wheelset.

d) The operation hours can be evaluated based on calculation or expert estimation method.

8.2.1.1.1. Calculation of operation hours

- For the calculation the following parameters have to be considered: OHJ (operation hours J): Journey-time of the vehicle from the origin to the destination, for freight wagons inclusive shunting time as well as time for delivery and collection to / from the customer.
- OHL (operation hours loading / unloading): Time need for loading and/or unloading, for example time after delivery of the wagon for loading till the collection from the customer (the journey-time OHA starts after the collection). This parameter only apply to freight wagons.

- OHML: Time need for the delivery and collection of the vehicles for planned maintenance in the workshop including the maintenance time for measures in service (MIS) as the wheelsets are mounted in the vehicle. The procedure will be the same for other spare parts mounted in the vehicle.
- OHPR: Time need for the provision of the vehicles for passenger coaches and trainsets e.g. replenish of operating supplies, cleaning, preheating and so on
- n: number of one-way runs, the outward journey and the return journey will be a complete round trip and counted as 2.
- k: number of service stops for equipping passenger coaches….
- m: number of maintenance events

Operation hours / year of a freight wagon: = n * (OHJ + OHL) + m * OHML

Operation hours / year of a passenger coach: = n * OHJ + k * OHPR + m * OHML

Operation hours of the single rail vehicle can be:

- derived from the vehicle mileage counter
- estimated from train operation data (train number and their destination) or time table

8.2.1.1.2. Expert estimation of operation hours

If no data is available, the following estimation scheme can be used:

- DIST [km]: Average distance between source and destination according to the track net
- v [km/h]: Middle cruising speed of the railway operator
- r [..]: Number of one-way runs per year (the outward journey and the return journey will be a complete round trip and counted as 2)
- MIS-DC [h]: Time expenditure for the maintenance in service (MIS) incl. delivering and collecting the vehicle

Operation h/year = DIST / v * r + MIS-DC

8.2.1.2. Determination of the number of components

The number of components is collected in the second table in the MS Excel sheet "operation data".

			Anzahl Einheiten Number of units Nombre de component					
		Komponente, inklusive derjenigen in der schweren Instandhaltung Component, including those beeing in stock in and in heavy maintenance Component, inclus la nombre définit sur stock et dans le maintien lourd	Gesamt* Totale*	Betreiber 1 Operator 1 Operateur 1	Betreiber 2 Operator 2 Operateur 2	Betreiber 3 Operator 3 Operateur 3	Betreiber 4 Operator 4 Operateur 4	Betreiber 5 Operator 5 Operateur 5
Mengengerüst Quantity structure Cadre estimatif	Eurofima	Radsatz Wheelset Essieu monté	1.800	1.000	800			
	Freight 22,5 to not thermostable (ORE)		2.500	500	2.000			
	Freight 22,5 to thermostable		6.200	200	3.000	3.000		
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		4.000				4.000	
	Eurofima	Radsatzwelle axle Essieu - axe	1.800	1.000	800			
	Freight 22,5 to not thermostable (ORE)		2.500	500	2.000			
	Freight 22,5 to thermostable		6.200	200	3.000	3.000		
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		4.000				4.000	
	Eurofima	Radscheibe wheel Roue	3.600	2.000	1.600			
	Freight 22,5 to not thermostable (ORE)		5.000	1.000	4.000			
	Freight 22,5 to thermostable		12.400	400	6.000	6.000		
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		8.000				8.000	
	Eurofima	Radsatzlager Bearings Palier	3.600	2.000	1.600			
	Freight 22,5 to not thermostable (ORE)		5.000	1.000	4.000			
	Freight 22,5 to thermostable		12.400	400	6.000	6.000		
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable		8.000				8.000	
	Eurofima		0					

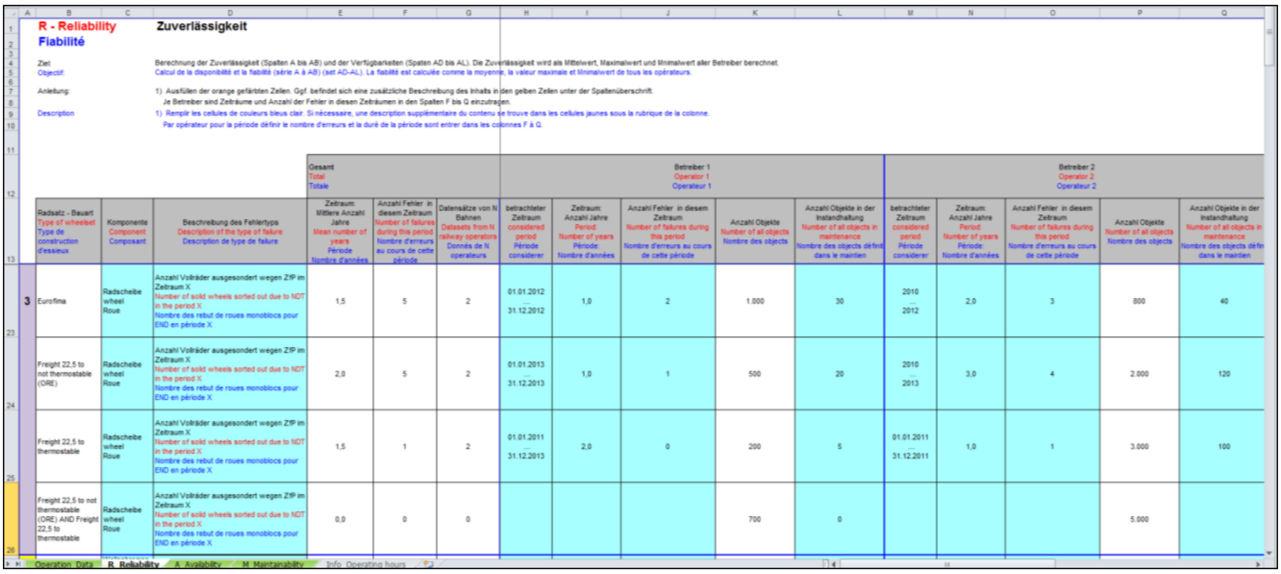
Table 10 - Second Screenshot of sheet "Operation_Data" (input values are examples)

8.2.2. Sheet "R_Reliability"

Based on the operation data for the defined failure types (column D) the reliability rates (columns BG to BM) are calculated.

The table comprises 71 columns, from A till column BS.

For up to 5 operators the following data can be inserted: "considered period", "Period: Number of years", "Number of failure during this period" and "Number of all objects in maintenance" ("Number of all objects in maintenance" is just for information purpose, these figures have no effect on the resulting reliability), see columns H to AJ.



R - Reliability
Fiabilité

Zuverlässigkeit

Ziel: Berechnung der Zuverlässigkeit (Spalten A bis AB) und der Verfügbarkeiten (Spaten AD bis AL). Die Zuverlässigkeit wird als Mittelwert, Maximalwert und Minimalwert aller Betreiber berechnet.
Objectif: Calcul de la disponibilité et la fiabilité (série A à AB) (set AD-AL). La fiabilité est calculée comme la moyenne, la valeur maximale et Minimalwert de tous les opérateurs.

Anleitung: 1) Ausfüllen der orange gefärbten Zellen. Ggf. befindet sich eine zusätzliche Beschreibung des Inhalts in den gelben Zellen unter der Spaltenüberschrift.
Je Betreiber sind Zeiträume und Anzahl der Fehler in diesen Zeiträumen in den Spalten F bis Q einzutragen.
Description: 1) Remplir les cellules de couleurs bleus clair. Si nécessaire, une description supplémentaire du contenu se trouve dans les cellules jaunes sous la rubrique de la colonne.
Par opérateur pour la période définir le nombre d'erreurs et la duré de la période sont entrer dans les colonnes F à Q.

				Gesamt / Total / Totale			Betreiber 1 / Operator 1 / Operateur 1					Betreiber 2 / Operator 2 / Operateur 2				
	Radsatz - Bauart / Type of wheelset / Type de construction d'essieux	Komponente / Component / Composant	Beschreibung des Fehlertyps / Description of the type of failure / Description de type de failure	Zeitraum: Mittlere Anzahl Jahre / Mean number of years / Période Nombre d'années	Anzahl Fehler in diesem Zeitraum / Number of failures during this period / Nombre d'erreurs au cours de cette période	Datensätze von N Bahnen / Datasets from N railway operators / Donnés de N operateurs	betrachteter Zeitraum / considered period / Période considerer	Zeitraum: Anzahl Jahre / Period: Number of years / Période: Nombre d'années	Anzahl Fehler in diesem Zeitraum / Number of failures during this period / Nombre d'erreurs au cours de cette période	Anzahl Objekte / Number of all objects / Nombre des objects	Anzahl Objekte in der Instandhaltung / Number of all objects in maintenance / Nombre des objects définit dans le maintien	betrachteter Zeitraum / considered period / Période considerer	Zeitraum: Anzahl Jahre / Period: Number of years / Période: Nombre d'années	Anzahl Fehler in diesem Zeitraum / Number of failures during this period / Nombre d'erreurs au cours de cette période	Anzahl Objekte / Number of all objects / Nombre des objects	Anzahl Objekte in der Instandhaltung / Number of all objects in maintenance / Nombre des objects définit dans le maintien
3	Eurofima	Radscheibe wheel Roue	Anzahl Vollräder ausgesondert wegen ZfP im Zeitraum X / Number of solid wheels sorted out due to NDT in the period X / Nombre des rebut de roues monoblocs pour END en période X	1,5	5	2	01.01.2012 ... 31.12.2012	1,0	2	1.000	30	2010 ... 2012	2,0	3	800	40
	Freight 22,5 to not thermostable (ORE)	Radscheibe wheel Roue	Anzahl Vollräder ausgesondert wegen ZfP im Zeitraum X / Number of solid wheels sorted out due to NDT in the period X / Nombre des rebut de roues monoblocs pour END en période X	2,0	5	2	01.01.2013 ... 31.12.2013	1,0	1	500	20	2010 ... 2013	3,0	4	2.000	120
	Freight 22,5 to thermostable	Radscheibe wheel Roue	Anzahl Vollräder ausgesondert wegen ZfP im Zeitraum X / Number of solid wheels sorted out due to NDT in the period X / Nombre des rebut de roues monoblocs pour END en période X	1,5	1	2	01.01.2011 ... 31.12.2013	2,0	0	200	5	01.01.2011 ... 31.12.2011	1,0	1	3.000	100
	Freight 22,5 to not thermostable (ORE) AND Freight 22,5 to thermostable	Radscheibe wheel Roue	Anzahl Vollräder ausgesondert wegen ZfP im Zeitraum X / Number of solid wheels sorted out due to NDT in the period X / Nombre des rebut de roues monoblocs pour END en période X	0,0	0	0				700	0				5.000	

Operation_Data | R_Reliability | A_Availability | M_Maintainability | Info_Operating hours

Table 11 - First Screenshot of sheet "R_Reliability" (input values are examples)

The structure of this sheet is as following:

- Column C: Definition of the component

Note that in sheet "Operation_data" up to four types of objects can be defined. For them the reliability calculation is done parallel, see numbering in column A. Comparing the four types of objects the chosen component in column C shall be identical.

- Column D: Definition of the failure type having influence on the reliability and finally on the availabilty of the component.
- Columns H to AF: Input of following data: "considered period", "Number of years", "Number of failures during this period" for up to five operators. The results of columns E and F will be used for further calculations.
- Columns AN: Definition of the unit ("h", "km", "Gross tkm") for to calculate the reliability result.

Except Column AN all other columns between AK and BM will be calculated automatically

- Column BN: The unit to describe the reliability value MTBF (Mean Time Between Failure) is set, in standard case it will be "years".
- Column BR: The desired mean reliability number for the future is set here.

Based on these results (columns BM and BR) the availability is calculated in slide "A_Availability" (see next chapter).

8.2.3. Sheet “A_Availability”

To improve the system the availability is calculated for the current situation (today) and for the future. The calculation is based on the unit hours “h”.

The calculation of the reliability is based on the defined failures per component (see sheet “R_Reliability”) and therefore a single component can comprise several reliability calculations. For example, the results of columns 15, 19 of sheet “R_Reliability” are added as inverse value in column E in sheet A_Availability. Due to experience in the railway business the general used terms “preventive maintenance” and “corrective maintenance” were not be applied and were replaced by the following term normally used in the sector: “maintenance in service” and “maintenance off the vehicle”, with the definitions listed below. The term “Time needed for logistic and administrative issues” is divided in “in service” and “off vehicle maintenance” to have a reference to the timespan (or different units, if adopted) and is calculated in the traditional way.

- <u>Time needed for maintenance in service (MIS)</u>: comprises the time span to maintain and check the system (e.g. the wheelset) under / in the vehicle in normal operation conditions. The time counted is the time for the system for one downtime event. When maintaining in the workshop, the time starts when the vehicle is in the workshop.
- <u>Time needed for maintenance off the vehicles (MOV):</u> comprises the time span to maintain and check the system (e.g. the wheelset) off the vehicle. The time counted is the time for the system for one downtime event.
- <u>Time needed for logistic and administrative issues for maintenance in service (LAMIS) and Time needed for logistic and administrative issues for maintenance off the vehicles (LAMOV):</u> comprises the time the component is not useable till the component is repaired, reassembled and ready for use. That means e.g. the time needed for transporting the component to and from the workshop, time for ordering spare parts, waiting time in case of overflow of the workshop, or time for preparing the maintenance activity. For wheelsets the time needed dismounting and mounting is also included.

In case that different times are needed for maintenance actions in one class of maintenance (MIS, MOV, LAMOV, LAMIS) the user have to consider an average time needed for these different types of operation.

The mentioned times always refer exclusively to a unit. If for example the primary suspension of a vehicle is broken, the vehicle is taken to the workshop, the built-in wheelset therefore is not available either. The wheelset is not the cause, though, the failure of the suspension therefore cannot be accused of to the reliability of the wheelset. This failure of the suspension has to be accused to the reliability of the vehicle, because the suspension is a component of the vehicle. That the suspension is a part of the vehicle this is shown by the product structure of the vehicle (= Internal Functional Analysis (IFE) of the vehicle).

The four types of availability differ in their range of covering time:

- Inherent availability: ➔ time (in service maintenance => MIS)
- Logistic availability MIS: ➔ time (in service maintenance + logistic time => MIS + LAMIS)
- Technical availability: ➔ time (in service maintenance + off vehicle maintenance => MIS + MOV)
- Total availability: ➔ time (in service maintenance + off vehicle maintenance + logistic time => MIS + MOV + LAMOV + LAMIS)

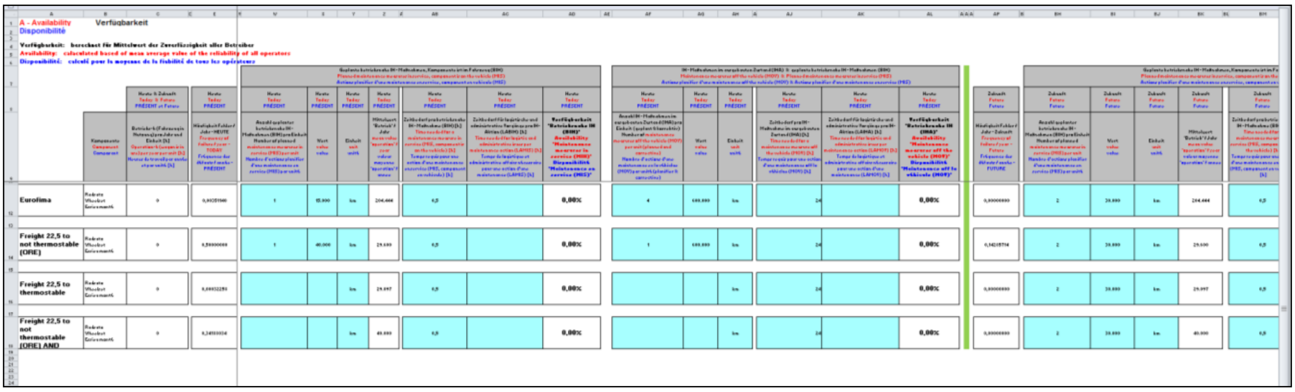
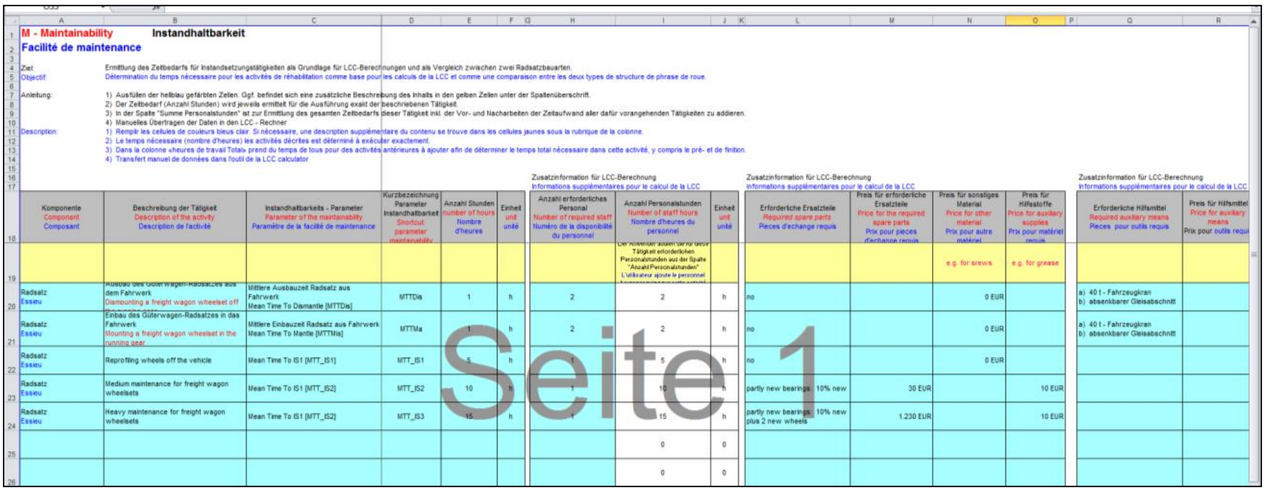


Table 12 - Screenshot of sheet “A_Availability” (input values are examples)

8.2.4. Sheet “M_Maintainability”

In this slide for maintenance activities the staff time and the need of means of production will be calculated. The result might be used as input for the slide “A_Availability” as well as for LCC.



M - Maintainability Instandhaltbarkeit
Facilité de maintenance

Ziel: Ermittlung des Zeitbedarfs für Instandsetzungstätigkeiten als Grundlage für LCC-Berechnungen und als Vergleich zwischen zwei Radsatzbauarten.
Objectif: Détermination du temps nécessaire pour les activités de réhabilitation comme base pour les calculs de la LCC et comme une comparaison entre les deux types de structure de phrase de roue.

Anleitung:
1) Ausfüllen der hellblau gefärbten Zellen. Ggf. befindet sich eine zusätzliche Beschreibung des Inhalts in den gelben Zellen unter der Spaltenüberschrift.
2) Der Zeitbedarf (Anzahl Stunden) wird jeweils ermittelt für die Ausführung exakt der beschriebenen Tätigkeit.
3) In der Spalte "Summe Personalstunden" ist zur Ermittlung des gesamten Zeitbedarfs dieser Tätigkeit inkl. der Vor- und Nacharbeiten der Zeitaufwand aller dafür vorangehenden Tätigkeiten zu addieren.
4) Manuelles Übertragen der Daten in den LCC - Rechner

Description:
1) Remplir les cellules de couleurs bleus clair. Si nécessaire, une description supplémentaire du contenu se trouve dans les cellules jaunes sous la rubrique de la colonne.
2) Le temps nécessaire (nombre d'heures) les activités décrites est déterminé à exécuter exactement.
3) Dans la colonne «heures de travail Total» prend du temps de tous pour des activités antérieures à ajouter afin de déterminer le temps total nécessaire dans cette activité, y compris le pré- et de finition.
4) Transfert manuel de données dans l'outil de la LCC calculator

Komponente / Component / Composant	Beschreibung der Tätigkeit / Description of the activity / Description de l'activité	Instandhaltbarkeits - Parameter / Parameter of the maintainability / Paramètre de la facilité de maintenance	Kurzbezeichnung Parameter Instandhaltbarkeit / Shortcut parameter maintainability	Anzahl Stunden / number of hours / Nombre d'heures	Einheit / unit / unité	Anzahl erforderliches Personal / Number of required staff / Numéro de la disponibilité du personnel	Anzahl Personalstunden / Number of staff hours / Nombre d'heures du personnel	Einheit / unit / unité	Erforderliche Ersatzteile / Required spare parts / Pieces d'echange requis	Preis für erforderliche Ersatzteile / Price for the required spare parts / Prix pour pieces d'echange requis	Preis für sonstiges Material / Price for other material / Prix pour autre matériel	Preis für Hilfsstoffe / Price for auxiliary supplies / Prix pour matériel requis	Erforderliche Hilfsmittel / Required auxiliary means / Pieces pour outils requis	Preis für Hilfsmittel / Price for auxiliary means / Prix pour outils requis
							Der Anwender addiert die für diese Tätigkeit erforderlichen Personalstunden aus der Spalte "Anzahl Personalstunden" L'utilisateur ajoute le personnel …				e.g. for srews	e.g. for grease		
Radsatz Essieu	Ausbau des Güterwagen-Radsatzes aus dem Fahrwerk Dismounting a freight wagon wheelset off …	Mittlere Ausbauzeit Radsatz aus Fahrwerk Mean Time To Dismantle [MTTDis]	MTTDis	1	h	2	2	h	no		0 EUR		a) 40 t - Fahrzeugkran b) absenkbarer Gleisabschnitt	
Radsatz Essieu	Einbau des Güterwagen-Radsatzes in das Fahrwerk Mounting a freight wagon wheelset in the running gear	Mittlere Einbauzeit Radsatz aus Fahrwerk Mean Time To Mantle [MTTMa]	MTTMa	1	h	2	2	h	no		0 EUR		a) 40 t - Fahrzeugkran b) absenkbarer Gleisabschnitt	
Radsatz Essieu	Reprofiling wheels off the vehicle	Mean Time To IS1 [MTT_IS1]	MTT_IS1	5	h	1	5	h	no		0 EUR			
Radsatz Essieu	Medium maintenance for freight wagon wheelsets	Mean Time To IS1 [MTT_IS2]	MTT_IS2	10	h	1	10	h	partly new bearings: 10% new	30 EUR		10 EUR		
Radsatz Essieu	Heavy maintenance for freight wagon wheelsets	Mean Time To IS1 [MTT_IS2]	MTT_IS3	15	h	1	15	h	partly new bearings: 10% new plus 2 new wheels	1.230 EUR		10 EUR		
							0	0						
							0	0						

Table 13 - Screenshot of sheet “M_Maintainability” (input values are examples)