OPTIBOX - SOFTWARE TOOL FOR THE OPTIMAL DISTRIBUTION OF HOT BOX AXLE DETECTORS

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Abstract

Axle bearings may constitute a critical component with regards to safety due to the fact that they can present sudden failures. Hot box detectors are wayside devices that aim at identifying axle bearings with a high potential of failure. Therefore, it is important to place these sensors along the network in order to minimize the risk of axle bearing failures that could derive in train derailments. How many and where to install these wayside devices depends on the requirements of each country and on the available investment capacity. However, there is no tool in the market that helps the Infrastructure Managers to prioritize locations for hot box detectors. In this context, the OPTIBOX tool that is presented in this article appears as useful and easy-to-use tool to guide Infrastructure Managers in the selection of the most appropriate locations for hot box detectors according to historical data of the line and its main relevant characteristics, such as speed, type of trains or volume of traffic.

Keywords: axle bearing, hot box detectors, optimisation, OPTIBOX

1 Introduction

The monitoring of the axle bearings of rolling stock can be performed either by wayside systems either by onboard monitoring devices. Nowadays the most used monitoring systems are the Hot Axle Box Detectors (HABD), a wayside device that detect axle bearing faults based on the measurement of in-service axle bearing temperatures.
In terms of managing axle box detectors, the initial investment on the acquisition of HABD as well as its maintenance during the lifetime have to be taken into account by the Infrastructure Managers considering safety and economic aspects.
Currently, there is no tool available for the Infrastructure Managers to help deciding the physical distribution of the monitoring systems, namely hot axle box detectors, in a railway network. Therefore, within the MAXBE (Interoperable Monitoring, Diagnosis and Maintenance Strategies for AXle BEarings) project a software was developed to overcome this absence. The MAXBE project, funded by the European Commission and more details on the project results can be consulted on the website www.maxbeproject.eu. The developed software tool allows to define and it is a decision-aid support system, which assists the infrastructure manager in the decision of the physical distribution HABD within the railway network considering their own criteria regarding safety, quality of service and also taking into account the main guidelines for the installation of these devices in the railway network of each country. The tool, developed for the OPTImal distribution of hot BOx aXle detectors, was named OPTIBOX and it allows to consider historical and statistical data of the railway network, the risk

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associated to certain indicators and the importance assigned to each one of the pre-defined indicators in order to be able to identify the most critical aspects regarding the axle bearing failure in a railway network. The software is available in excel format programmed with Visual Basic to be a user-friendly one and it is easy to implement and very flexible to the end-users needs. At the end, the OPTIBOX is able to suggest the most adequate places to install a wayside monitoring system, a hot box axle detector or other type of device, considering a priority list that results from the historical data and also from the infrastructure managers experience and the risk assessment, which is included in the definition of the risk criteria and the importance attributed to each one of the defined indicators.
In this paper, a summary of the tool requirements is indicated. Then, the main features of the software tool along with the methodology employed in its development are explained. Furthermore, a case-study of the application of the tool into a realistic scenario is presented.

2 Requirements of wayside monitoring devices installation

Regarding the wayside monitoring devices installation, the European countries follow the recommendations of the European Standard EN 15437-1 [1]. Nevertheless, as this standard does not give recommendations for the strategic location of HBDs, usually each country has its own national requirements. Accordant to the EN 15437-1 [1], the requirements for wayside installation can be classified in four groups:

- requirements to assure a steady and clean recording of the signal; this aspect refers to the need of a stationary running of the train, which means that the wayside must be placed in a section where train runs at constant speed, preferably on straight alignment, far from switches and crossings, etc.
- requirements to minimize operational impact; this issue accounts for the aim of reducing as much as possible the traffic disruption in case of a detection of a hot axle box by the HBD; or this reason, HBD should be placed close to stations, a higher number of HBD should be installed in lines with higher traffic, etc. These requirements also include those related to safety issues, such as installing the HBD before tunnels or bridges to detect any failure before entering the tunnel or the bridge.
- requirements to minimize interferences with electrical/electronic equipment, giving special attention to the signaling system and the overhead line return current.
- other requirements, such environmental conditions (such as to avoid high changes of temperatures, etc.), or the risk of damage of theft.

3 Software tool

The main objective of the OPTIBOX tool is to help the user to identify the most suitable locations to install wayside devices to detect axle bearing failures such as the Hot Axle Box Detectors. The software (SW) was defined in an excel file and programmed with Visual Basic in order to be an easy-to-learn, easy-to-use tool and a flexible tool, straightforwardly implemented by potential users and adapted to satisfy the user's needs.
OPTIBOX is organised in two main parts, each one divided in several steps. The first part is the core part of the S tool and deals with the selection of the most suitable line segment to install the wayside diagnostic devices. It starts with the data input, where all the information regarding the network under analysis and its characteristics are introduced. Once the initial information is included, the following step is weighting. In this phase of the procedure, the user define which parameters are the most important ones, aspect that is important since criteria can vary from one Infrastructure Manager to another, However, the toll also proposes recommended values in order to guide the user in the definition of appropriate values.

Then, the user can proceed to the last step of the first stage: prioritisation. OPTIBOX creates a ranking of the line segments, according to the scores The second stage of the procedure starts from there and it aims to help the user to define the best location to install the wayside devices within the identified most suitable line segments. This stage can be split in two phases: definition of the general requirements from each country and definition of specific requirements, such as maximum distance to signalling lights, etc. Figure 1 shows the methodology of the software tool.

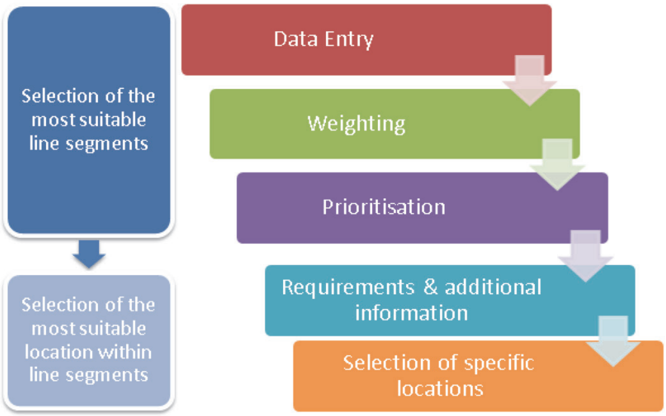


Figure 1 Methodology of the SW tool

4 Case study

A case study was developed to highlight the benefits of the OPTIBOX tool for the definition of the optimal physical distribution of wayside diagnostic systems (HBD). The example is based on realistic data (not real) of the Portuguese Railway Network. Real data are not used due to confidential reasons.

Section 1 – Input Information

In the first section of the tool, the preliminary information is included in the software tool by the infrastructure management company including the country in order to take into account the requirements of the installation of the wayside systems for that country identified previously, in this case study, the country is Portugal. Then, the railway line in the network to be analyzed needs to be selected in order to consider its specific features. In the present case study, a double railway line with a total length of 336 Km is considered and the aim is to find an optimal distribution of HABD for that line. The information to proceed with the analysis and included in the tool by the end user is the following:

- number of segments that should be considered in the analysis of that specific line.
- maximum distance of the segments into which the line is divided. This parameter can be defined by the user, but the distance of the segments should be smaller than the maximum distance between HABD defined in the standards available for the specific country.

Number of singular points defined according to the number of singular points that should be considered in that specific line for the purposes of this software tool, in which singular points can be considered as connection of a branch line or any other element that may cause any modification in the parameters defined for each segment, such as traffic, accidentability, speed and type of trains. Additionally, the information related with the “kilometric point” (KP) of each singular point of the line defined by the correspondent kilometre, should also be provided. In Table 1, the input included in section 1 is presented.

Table 1 Information included in the 1st stage

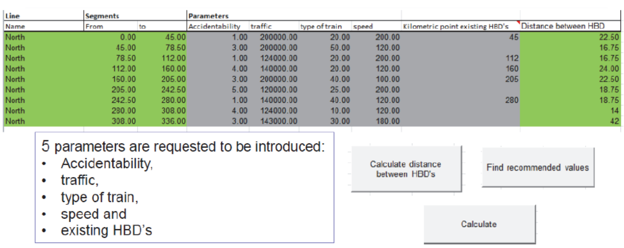
Information	
Country	Portugal
Line	Northern Line
Length of line (in km)	336
Segments to divide the line (length)	50
Number of singular points	5
Kilometre of each singular point (in Km)	45; 112; 160; 205; 280

Section 2 – Parameters

In the second section, several segments are generated automatically based on its initial and final KP and according to the information provided in the previous section 1. OPTIBOX will produce the segments considering the lower value between the maximum distance of each segment and the distance considering the singular points of the line. Then the following four parameters are used to characterize each segment:

- Speed (km/h) – maximum commercial speed at each section (considering the train that circulates with the highest speed). By considering this parameter, a higher level of priority is indirectly being given to high speed lines. Moreover, in many occasions higher speeds means less distance between HABD, and therefore, the worst case scenario regarding safety (maximum speed) should be considered. In the present case study, the speed is 220 km/h.
- Traffic (Tonnes/year) – the total tonnage of the line per year in each section, including freight and passenger trains. With this parameter, it is possible to give a higher level of importance to main lines usually with higher level of service (higher traffic). Furthermore, higher volume of trains means higher risk of axle bearing failures taking place in this line and more operational impact if a train has an accident or its travel has to be interrupted. In the case study, the railway line is a mixed one, and therefore, the total tonnage of freight and passenger trains in each section is included.
- Type of Trains (% of freight trains over total traffic) - ratio between the percentage of freight trains and the total traffic in each section. This aspect allows distinguishing the main use of the line and giving different levels of importance to the railway lines
- Accidentability (incident/year) - number of incidents that occur per year in each segment line.

In Figure 2, the parameters input interface are shown.



Line	Segments		Parameters					
Name	From	to	Accidentability	traffic	type of train	speed	Kilometric point existing HBD's	Distance between HBD
North	0.00	45.00	1.00	200000.00	20.00	200.00	45	22.50
North	45.00	78.50	3.00	200000.00	50.00	120.00		16.75
North	78.50	112.00	1.00	124000.00	20.00	200.00	112	16.75
North	112.00	160.00	4.00	140000.00	20.00	120.00	160	24.00
North	160.00	205.00	3.00	200000.00	40.00	100.00	205	22.50
North	205.00	242.50	5.00	120000.00	25.00	200.00		18.75
North	242.50	280.00	1.00	140000.00	40.00	120.00	280	18.75
North	280.00	308.00	4.00	124000.00	10.00	120.00		14
North	308.00	336.00	3.00	143000.00	30.00	180.00		42

Figure 2 Second input stage:parameters

The OPTIBOX estimates the most suitable location for implementation of new HBD as a decision support system, but considering the existing wayside monitoring systems already installed in the railway line. Therefore, in the second part of the SW, the information related to the number of existing HBDs is introduced mentioning the respective exact kilometric point. As an example, if there is a HABD installed in KP 45, the user should include 45 in the row of the segment with the correspondent interval (KP 50-60). In Table 2, the results calculated by OPTIBOX are presented.

Table 2 Mean and deviation parameters calculated by the SW

	Mean	Desv.
Accidentability	2.78	1.48
Traffic	154555.56	35025.39
Type of train	28.33	12.75
Speed	151.11	42.56
DIST between WDDs	21.78	8.25

Section 3

The attribution of weights allows defining the importance given to the parameters and it is divided in two steps. The software tool automatically produces a table with recommended values estimated based on the mean and deviation of each parameter. Considering this results (Table 3), the limit values of the intervals considered for each parameter are recommended as well as the correspondent weights. However, the user is able to define different values for the intervals and also the weights taking into account their experience and preferences. In Table 3, the estimated weigh parameters are presented for the case study.

Table 3 Example of weight of parameters

	Range		Total Weight	Points
Accidentability	From	To	30	
	0	2	20	6
	2	5	60	18
	5		100	30
Traffic	From	To	20	
	0	142690	10	2
	142690	355310	40	8
	355310		80	16
Type of train	From	To	10	
	0	40	30	3
	40	80	80	8
	80		90	9
Speed	From	To	20	
	0	100	10	2
	100	180	90	18
	180		100	20
DIST between WDDs	From	To	20	
	0	20	20	4
	20	60	80	16
	60		100	20

Section 4
Considering the information previously included in the SW tool, it is possible to estimate a priority list that presents the ranking of segments ordered by the segment that presents the highest importance in the installation of a HABD system to the segment with less priority. It should be noticed that this priority list is based on the weights defined by the user, and any modification of those parameter weights implies a new estimation of the priority list. The "Priority List" is estimated through the "Calculate" button presented in the second sheet of Excel SW tool. Part of the resulting priority list is presented in Table 4, where the segment with higher urgency to install a HABD is from KP 205.00 to KP 242.50.

Table 4 Example of priority list

Line ID	From	To	Descending order (priority for HABD installation)
North	205.00	242.50	58
North	308.00	336.00	56
North	45.00	78.50	54
North	160.00	205.00	52
North	112.00	160.00	41
North	280.00	308.00	41
North	0.00	45.00	35
North	242.50	280.00	34
North	78.50	112.00	29

After the identification of the track segments with higher priority, the user can determine a suitable HABD location regarding the recommended minimum distance from a HABD to a main signal.
In order to determine a suitable location within the selected line segments (those with higher score in the ranking), the OTIBOX tool considers significant parameters as the train speed, location of main signal, danger points, minimum distance from main signal, average distance between wayside devices, the train length and the braking distance diagnostics systems.
In all cases, it has to be guaranteed that the distance between HABD to be installed and main signal is large enough to allow the train to stop. For this minimum distance, a reaction time is included in the formulation in order to make sure that the alarm of a hot box can be noticed by the safety system and can be transferred to the signals along the line. This has been estimated in 120 seconds. On conventional lines the train driver must have the chance to see that a signal changes from "Drive" to "Stop".
As a result, the OBTIBOX tool provides a diagram where the user can see in a visual way which locations are possible with regards to the position of the main signals.

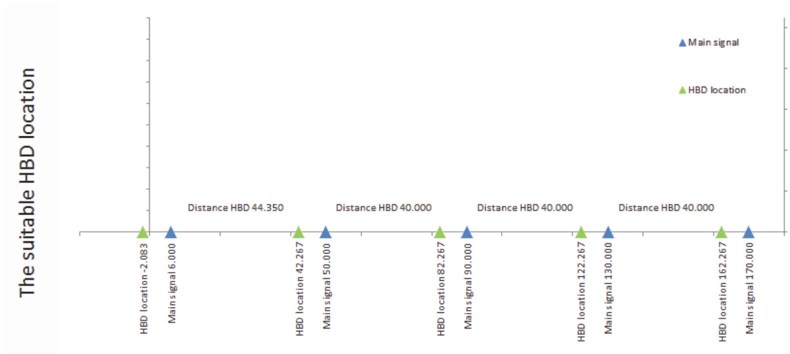


Figure 3 Diagram of HBD location

5 Conclusions

Unexpected axle-bearing failures can cause derailments, that should be prevented not only to avoid the disruption of traffic but specially to guarantee the safety of passengers. To the definition of the location to install the new wayside monitoring systems in order to obtain reliable monitoring data is fundamental to assess the correct condition of the axle bearing. Currently, European rail networks are provided with Hot Axle Box Detectors that detects axle bearings faults by the measurement of the in-service temperature. All the European countries follow the recommendations of standard EN 15437-1 [1] on the installation of HABD monitoring systems. Nevertheless, since the standard does not give recommendations for the strategic location of HBDs, each country follows its own national requirements, which means that significant differences can be found when it concerns to the distance between two consecutives HBD.
Within the MAXBE project, a software tool (OPTIBOX) was developed. In this paper, the main features of the software tool are described and a case-study is presented.

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