CEN/CEN WS IRIP

Date: 2024 – 10 - 07

Draft CWA XXXXX: XXXX

Workshop: XXX

Decision Support System for Highway Maintenance planning related with the automation of road maintenance technologies

ICS:

Decision Support System for Highway Maintenance planning related with the automation of road maintenance technologies

Contents

Foreword

This CEN Workshop Agreement (CWA XXXX:YYYY) has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid way to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the Workshop CEN/WS Intelligent Road intervention processes, the secretariat of which is held by UNE – Spanish association for standardization consisting of representatives of interested parties on 07-10-2024, the constitution of which was supported by CEN following the public call for participation made on 2024-08-08. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

The final text of this CEN Workshop Agreement was provided to [CEN and/or CENELEC] for publication on YYYY-MM-DD.

Results incorporated in this CWA received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 955269.

The following organizations and individuals developed and approved this CEN Workshop Agreement:

- CEMOSA – CENTRO DE ESTUDIOS DE MATERIALES Y CONTROL DE OBRA SA - Jose Solís-Hernández and Paula López Arévalo
- Università degli Studi di Genova – Alice Consilvio and Mohammad Abbasi
- LMS - Themis Anastasiou
- Tekniker - Ander Ansuategi
- EIFFAGE INFRAESTRUCTURAS S.A. – Rafael Martinez and Miguel Angel Aragón
- UPM – Jesús Rodríguez
- European Science Communication Institute gGmbH – Mara Van Welie
- CERIB – Thibaut Le Doeuff
- SPW – Gauthier Michaux

Attention is drawn to the possibility that some elements of this document may be subject to patent rights. CEN-CENELEC policy on patent rights is described in CEN-CENELEC Guide 8 “Guidelines for Implementation of the Common IPR Policy on Patent”. CEN shall not be held responsible for identifying any or all such patent rights.

Although the Workshop parties have made every effort to ensure the reliability and accuracy of technical and non-technical descriptions, the Workshop is not able to guarantee, explicitly or implicitly, the correctness of this document. Anyone who applies this CEN Workshop Agreement shall be aware that neither the Workshop, nor CEN, can be held liable for damages or losses of any kind whatsoever. The use of this CEN Workshop Agreement does not relieve users of their responsibility for their own actions, and they apply this document at their own risk. The CEN Workshop Agreement should not be construed as legal advice authoritatively endorsed by CEN/CENELEC.

Introduction

Most of the European road network was constructed between 1960 and 1970, and it was designed for a working life of 50 years [1]. This means that our roads are outdated, and this is normal nowadays. In the upcoming years, road infrastructure investment will be focused on smart solutions for road asset maintenance. Large interventions will be necessary since the road network is aged. We need technologies that are quick, efficient, safe and reliable.

To assess the magnitude of the potential impact of road asset maintenance in Europe, it is imperative to consider the scale of the market. In this sense, in the EU, government invest around EUR 112 billion a year in transport [2]. These investments are mostly dedicated to building and maintaining roads, highlighting the economic importance of the sector [1].

In addition, with the introduction of innovative monitoring technologies and sensors, high volume of data about the status of road infrastructure become available. The analysis of these data allows to extract meaningful information and knowledge which can be used for decision-making, turning information and intervention capabilities into real decisions. For this reason, the development of Decision Support Dystems (DSS) for highway maintenance planning is becoming an important and challenging goal for highway infrastructure managers.

This CEN Workshop Agreement defines a Decision Support System for the optimal planning of road maintenance interventions and resources, moving towards advanced maintenance strategies. In particular, this CWA does not prescribe any particular technology but rather present a comprehensive framework for implementing data-driven road asset management and maintenance planning [3]. The practical application of this Decision Support System will help to reduce regular maintenance costs, improve the efficiency of road maintenance planning and reduce traffic disruptions due to maintenance work.

This CWA has been elaborated as part of the EU-funded research project OMICRON, which received funding from the European Union's HORIZON 2020 research and innovation programme under grant agreement No. 955269.

1 Scope

This document describes the main functionalities, features, information workflow and elements of a Decision Support System for highway maintenance planning related with the automation of road maintenance technologies, proposing some guidelines for its implementation.

In particular, this CWA defines a Decision Support System for the optimal planning of road maintenance interventions and resources, moving towards advanced maintenance strategies. The Decision Support System's purpose is to provide condition analysis, prioritizations of maintenance activities and to suggest maintenance plans and work orders from the analysis of data.

Different Artificial Intelligence, simulations, predictions and optimizations techniques can be applied for this scope; however, the main desired functionalities can be identified and some guidelines for their development can be given.

The following guidelines are specified:

- Guidelines to select the needed inputs related with the infrastructure condition and traffic data.
- Guidelines to define the platform components including a data analysis module.
- Guidelines to define the information flow between the components.

- Guidelines for choosing the Key Performance Indicators (KPIs) related with the traffic and the impact on final users, the status of the asset or the maintenance performance.
- Guidelines for outputs visualisation by the infrastructure manager in an easy and user-friendly interface.

The Decision Support System for the optimal maintenance planning is developed to improve the availability and reliability of the infrastructure. Infrastructure condition aspects as well as operational aspects are used in the maintenance plan elaboration for predictive planning, booking of road possession and work zones management. To define the active work zones, the road sections to be maintained and the optimal allocation of maintenance interventions to time intervals should be defined considering traffic flows.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 55000:2014 – Asset management

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

3.1

Decision Support System

Software designed to support decision-making processes.

3.2

Data analysis

systematic investigation of relevant, evidence-based information (3.1.127) obtained in monitoring (3.1.155) the process (3.1.190) and its flow in a real or planned system.

[SOURCE: ISO 22300:2021(en), definition 3.1.71]

3.3

Machine Learning

process of optimizing model parameters (3.1.2) through computational techniques, such that the model's behaviour reflects the data or experience.

[SOURCE: ISO/IEC 4879:2024(en), definition 3.1.3]

3.4

Random Forest

a machine learning algorithm that combines the output of multiple decision trees to reach a single result and handles both classification and regression problems.

3.5

Structural Health Monitoring

process that involves the continuous or periodic monitoring of structures such as buildings, bridges, dams, and infrastructure systems to assess their integrity and detect potential damage or deterioration.

3.6

(Internet of Things) IoT

infrastructure of interconnected entities, people, systems and information resources together with services which processes and reacts to information from the physical world and virtual world.

[SOURCE: ISO/IEC 19944-2:2022(en), 3.1]

3.7

Artificial intelligence (AI)

capability of a functional unit to perform functions that are generally associated with human intelligence such as reasoning and learning

[SOURCE: ISO/IEC 2382:2015(en), 2123770]

3.8

Optimisation

decision-making strategy to meet the business objective under a weighted set of conditions and concerns.

[SOURCE: ISO 15746-1:2015, 2.13]

3.9

Objective function

formula that relates a decision variable to either the cost or the revenue of an alternative

cf. cost function, income function.

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.2655]

3.10

User Interface

component of an interactive system (software or hardware) that provides the information and controls necessary for the user to accomplish specific tasks with the interactive system.

[SOURCE: ISO 1503:2008, 3.17]

3.11

Key Performance Indicator (KPI)

qualitative and quantitative measure that demonstrates critical success factors of the people in an organization.

Note 1 to entry: Key performance indicators differ depending on organizational goals and are often used as determinants for evaluating performance (3.2.12).

[SOURCE: ISO 30400:2022, 3.2.13]

3.12

Level of transport service

rating of the quality of transportation facilities and services from the user perspective, with reference to speed, travel time, freedom to manoeuvre or traffic interruptions.

[SOURCE: ISO/TS 17573-2:2020(en), 3.114]

3.13

International Roughness Index (IRI),

standardised measure of road roughness, i.e. the overall ride quality of an asphalt road pavement. Essentially, it is a measurement of pavement smoothness.

3.14

Sideways Force Coefficient (SFC)

SFC is the measure that the SCRIM® machine uses to represent the skidding resistance that a road surface provides. The higher the SFC, the greater the level of skid resistance that the road surface provides.

3.15

Geographical Information Systems (GIS)

in the strictest sense, a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations

[SOURCE: ISO 24512:2024(en), 3.8]

3.16

Building Information Modelling (BIM)

use of a shared digital representation of an asset to facilitate design, construction and operation processes to form a reliable basis for decisions.

[SOURCE: ISO 22057:2022(en), 3.3.10]

4 Functionalities of a Decision Support System for Highway Maintenance planning

A Decision Support System for Highway Maintenance planning should perform some main functionalities, each dedicated to performing a specific task.

The main considered functionalities are reported in this section.

4.1 Functionality 1: Asset condition analysis

This functionality uses asset condition data to analyse and represent asset condition. It can be applied to different assets such as pavement, bridges, tunnels, earthworks, signalling, safety elements, drainage, lighting and installation, etc. It can include the following tasks: road assets' parameters analysis, calculation, estimation and road segmentation.

The results of the asset condition analysis can be:

- Estimation of road parameters and quality indexes depending on different road assets and measurements.
- Estimation of parameters evolution with time.

- The estimation of degradation levels and related thresholds to classify the asset condition (such as excellent, good, bad and critical condition).
- Identification of damage in road infrastructures.
- Location of damage in road infrastructures.
- Alarms that notify abnormal behaviour on different assets.

Different techniques could be applied according to the different assets and data quantity and types, for example, artificial intelligence and machine learning algorithms, physical degradation models, structural analysis, structural health monitoring techniques, etc.

4.2 Functionality 2: Traffic impact analysis

This functionality is specific for maintenance planning problem related to transport infrastructure and consists in the evaluation of the impact on traffic due to maintenance. It is related to the management of work zones which have a significant impact on traffic and on highway level of service, according to their configuration and the duration of the maintenance works.

Different techniques such as traffic simulation approaches can be applied to estimate this impact, according to the type and availability of traffic data.

4.3 Functionality 3: Maintenance planning

This functionality allows to plan maintenance activities. The goal is the mitigation of work zones impact on traffic, improving infrastructure condition and reliability at the same time. The functionality takes as inputs the information on the infrastructure status and on traffic from the functionalities 1 and 2.

The output consists in the definition of:

- The order in which the road sections need to be maintained.
- The optimal allocation of maintenance interventions to time intervals.
- The configuration of the active work zones among the options defined by regulation.

5 Guidelines for the development of a Decision Support System for Highway Maintenance planning

In this section, the guidelines for the development of a Decision Support System for Highway Maintenance are proposed.

5.1 Inputs data

The system shall consider infrastructure condition data, traffic data and operational data considering the static or dynamic character of the data.

The main types of data are:

- Historical data on asset condition which include inspection outputs such as parameters to assess asset condition used by the infrastructure manager. Examples are International Roughness Index (IRI), Side Force Coefficient (SFC) and deflections for road pavement.
- Assets real-time monitoring data, such as from the IoT monitoring information technologies from bridges.
- Maintenance data. Information relative to previously performed maintenance activities as well as the planned work orders.
- Traffic information. Traffic data and their variation over time in the different highway sections.

5.2 Platform components

The system should include a module for traffic impact analysis, a module for asset condition analysis, a module for maintenance planning and a user interface.

An example is represented in Figure 1.

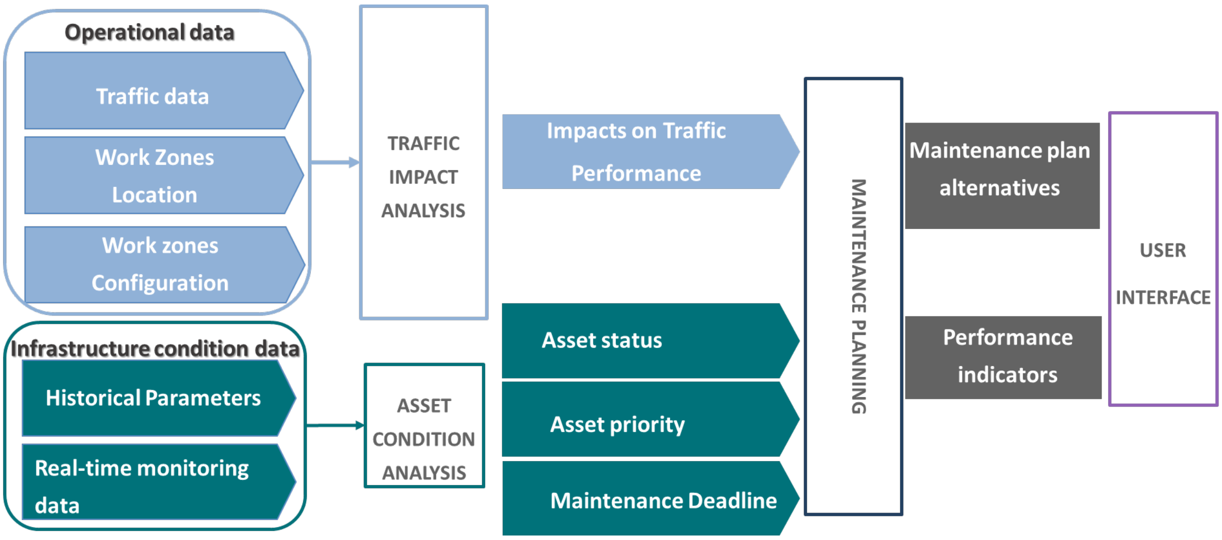

Figure 1 - Recommended Components and Connections for the Decision Support System

Operational data such as traffic data and work zone management data are used as input by the module of traffic impact analysis to estimate the impacts on traffic performance according to work zone position and configuration.

Infrastructure condition data, both historical and real-time, are instead analysed by the asset condition module to estimate the asset status, its criticality and the deadline for maintenance execution.

The maintenance planning module takes as inputs the results of the traffic impact analysis and the asset condition analysis such as the impact on traffic performance and the assets degradation level (excellent, good, poor and critical).

The outputs are the maintenance plans and the related performance indicators to be visualised on the user interface.

5.3 Information workflow

The information workflow between the components should be defined, specifying the inputs and outputs of each module. An example of the information workflow is represented in Figure 2.

The workflow highlighted in red colour regards the functionalities of "Asset condition analysis", the workflow highlighted in blue regards the functionality of "Traffic impact analysis", while the part of the diagram highlighted in purple regards the "Maintenance planning" functionality. The diagram shows how the three functionalities are linked, and which information is exchanged.

Historical data and real-time data are received, pre-processed and analysed to predict and assess the assets' condition. If road condition data are available, road section with homogeneous degradation level can be defined. This information is then used as input in the maintenance planning.

Within the maintenance planning functionalities, three main sources of data are considered: the traffic data, the maintenance data and the infrastructure condition data. Traffic data is pre-processed and analysed to estimate the impact of work zones on traffic. The analysis takes into account also the information about maintenance work zone derived from the maintenance data. The estimated traffic impact is then used as input in the maintenance planning process.

The maintenance data are pre-processed and analysed to estimate maintenance activity types, their duration and work zone configurations.

This information is considered in the maintenance planning, as well as the condition evaluation and the traffic analysis, to prioritise and plan maintenance activities.

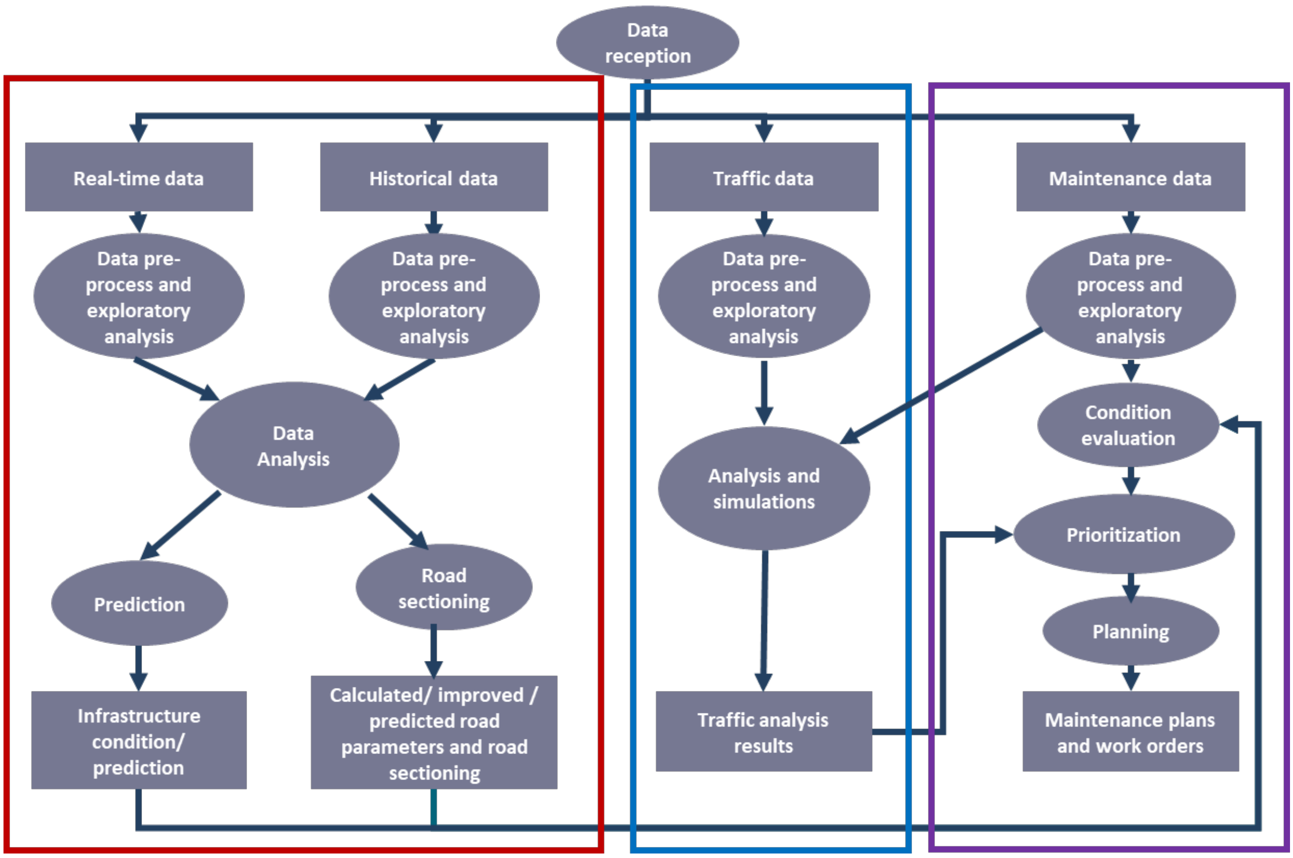

Figure 2 - Information workflow

5.4 Key Performance Indicators

The KPIs for maintenance planning represent the main objectives that the infrastructure manger wants to achieve in the management of the highway maintenance.

The main types of KPIs are reported in Table 1.

Table 1 - KPIs

Target	**Indicator**	**Detailed indicators**
Safety	Users' safety	Number of accidents involving road users Number of persons seriously injured and killed
	Workforce safety	Number of accidents involving road workers Number of workers seriously injured and killed
Performance	Traffic performance	Travel time delay
		Traffic volume
		Vehicles queue length
		Level of service
		Vehicles speed
	Maintenance performance	Maintenance cost
		Maintenance completion time
		Number of major interventions
		Total investment expenditures
		Total traffic management expenditures due to work zones
		Total renewal expenditures
Availability	Infrastructure availability	Number of assets failures in relation to traffic volume
		Number and duration of traffic disruptions (highway section closure)
		Number and length of active work zones in a defined highway section
		Work zone duration per each configuration in a given time period
		Temporary speed restrictions
		Network capacity
		Degree of network utilisation
Reliability	Condition	Asset degradation level (number of assets/segments in excellent, good, bad, critical condition)
		Number of asset failures
		Number of corrective maintenance interventions
		Number of urgent restorations after accidents

5.5 User Interface

Another key element within the Decision Support System is the way of transmitting the important outputs from the different analysis to their users. In this document, it is proposed the creation of a user interface that allows managers to obtain these useful results in a readable and user-friendly way, without the need of any previous knowledge on the algorithms applied, on programming or data science or the knowledge of a specific software. Some relevant DSS interface elements that could be added to any DSS are the following:

- The visualisation of assets in an interoperable Building Information Modelling – Geographical Information System (BIM-GIS) environment.
- The access to the information stored on the database.
- The visualisation of the infrastructure's state which is the result of the analysis and predictions.
- The visualisation of the maintenance planning obtained by using Artificial Intelligence and advanced optimisation techniques.
- The visualisation of the traffic volume in the network impacted by the maintenance work zones.

The GIS visualization should allow the visualization of the work zones and the different highway assets. For each work zone, detailed information should be provided, such as work zone ID, starting and ending dates, suggested configuration and type of maintenance activity. In addition, for each asset, the information stored in the database should be displayed as well as the results from the asset condition analysis, with the prediction of the main parameters that represent the asset status.

The interface on maintenance planning should display the planned maintenance interventions in a Gantt chart. The Gantt chart can show the work zones that will be maintained in the different dates. This information can be filtered by dates, and it is interconnected to the GIS visualisation. The maintenance Key Performance Indicators can be displayed in a bar chart. A calendar can show the average traffic volume in the different days of the selected time period, highlighting the traffic peak days.

Bibliography

[1] Martijn Brons, Lewis Dijkstra, Juan Nicolás Ibáñez, Hugo Poelman "Road Infrastructure in Europe: road length and its impact on road performance", EC Directorate-General for Regional and Urban Policy, Working Paper 03/2022. https://ec.europa.eu/regional_policy/sources/work/road-2022/road-infrastructure-2022.pdf

[2] Eurostat GOV_10A_EXP

[3] ISO 55001:2024(en) Asset management — Asset management system — Requirements