Application de la stratégie d'adaptation au changement climatique de l'UE au secteur ferroviaire.

Applying the EU's climate change adaptation strategy to the rail sector.

MULLARD Hubert
SNCF-Voyageurs
Le Mans (France)
hubert.mullard@sncf.frl

CLÉMENT Philippe
SNCF-Voyageurs
Le Mans (France)
philippe.clement@sncf.fr

Résumé — Malgré la volonté mondiale de limiter la hausse des températures à 1,5°C [1], les effets dévastateurs du changement climatique sont évidents, il entraînera toutes sortes de risques et affectera les chemins de fer.

Les travaux présentés ici s'inscrivent dans le cadre du projet de recherche européen pour un système ferroviaire durable, Rail4EARTH et de son Work Package 2 (WP2) Adaptation to Climate Change (ACC), qui vise à accroître la résilience du système ferroviaire européen aux conditions climatiques actuelles et futures.

La méthode consiste à mettre en œuvre la stratégie d'adaptation de l'UE au secteur ferroviaire, structurée à ce stade autour de ses deux premiers objectifs "Smarter adaptation" (adaptation plus intelligente) et "Faster adaptation" (adaptation plus rapide).

L'approche choisie consiste à collecter, partager et comparer les connaissances existantes sur les outils d'évaluation et les solutions d'adaptation. Ces connaissances sont acquises par le biais d'analyses documentaires, de présentations détaillées du retour d'expérience et d'initiatives internes des entreprises du consortium.

L'analyse de la base de connaissances a mis en évidence la nécessité de réaliser des études de vulnérabilité pour l'ensemble des actifs ferroviaires.

L'approche de corrélation entre les données de maintenance, les événements d'exploitation et les données climatiques est confirmée comme une méthodologie pertinente et robuste pour évaluer la vulnérabilité des actifs ferroviaires, y compris le matériel roulant.

Mots-clefs — changement climatique, résilience, adaptation, chemin de fer, actifs.

Abstract — Despite the global resolve to limit the rise in temperature to 1.5°C [1], the devastating effects of climate change are clear to see, it will entail all kinds of risks and will affect the railways.

The work presented here is part of the European research project for a sustainable rail system, Rail4EARTH. And its Work Package 2 (WP2) Adaptation to Climate Change (ACC), which aims to increase the resilience of the European rail system to current and future climate conditions.

The method is to implement the EU adaptation strategy to the railway sector, structured at this stage around its two first objectives 'Smarter adaptation' and 'Faster adaptation'.

The chosen approach is to collect, share and benchmark existing knowledge on assessment tools and adaptation solutions. This knowledge is acquired through literature reviews, detailed presentations of return of experience, and internal initiatives by the companies in the consortium.

Analysis of the knowledge base has highlighted the need to carry out vulnerability studies for all railway assets.

The correlation approach between maintenance data, operating events and climate data is confirmed as a relevant and robust methodology for assessing the vulnerability of railway assets, including rolling stock.

Keywords — climate change, resilience, adaptation, railway, assets.

I. INTRODUCTION

Despite the global will to limit the rise in temperature to 1.5°C [1], the devastating effects of climate change are obvious. Climate change is a fact and last IPCC assessment report [2] confirms that global warming will continue to increase over the coming decades. It will bring with it all kinds of risks: more frequent extreme weather events such as heatwaves, droughts, or floods, to coastal erosion due to rising sea levels. The impacts will affect every human activity. Railway is one of them, and as it is one of the best solutions to dramatically reduce GHG emitted by transportation [3], making it resilient is crucial.

The work presented is a part of the European research project for a sustainable rail system, Europe's Rail flagship project #4 named Rail4EARTH. The four-year project started in December 2022. This paper presents the research undertaken as part of WP2 (Work Package 2) Adaptation to Climate Change (ACC), which aims to increase the resilience of the European railway system to the current and future climate conditions.

The method is to implement the EU adaptation strategy [4] to the railway sector, structured at this stage around its two first objectives 'Smarter adaptation' and 'Faster adaptation'.

Railway operators, infrastructures managers, train manufacturers will bring their expertise and experiences to the project: SNCF (France - Leader), ADIF (Spain), ALSTOM (France), PKP (Poland), Trafikverket (Sweden).

Regarding 'Smarter adaptation', the objective is to develop knowledge on climate change adaptation related to the railway assets design in order to make them resilient to the predict-ed climate scenarios for the coming decades, as their life duration ranges from 40 years (trains) to 100 years (infrastructure).

Concerning 'Faster adaptation', some geographical areas in the World are certainly currently facing the future climate conditions of Europe: the technical solutions already implemented for railway activities will be benchmarked.

II. FRAMEWORK AND SCOPE OF THE STUDY

When considering the activities needed to minimise the impacts of climate change by increasing resilience, mitigation and adaptation are often confused, even though they are in fact different issues requiring very different modes of action. Although the study focuses solely on adaptation to climate change, given the scale of the subject and the fact that it is the very first step, it was necessary to limit the scope of the study. Thus, in phase 1 of the European project, only railway assets are considered (rolling stock, infrastructure, and station). The adaptation of maintenance and operation, linked to organisation and resources (equipment and personnel), should be ad-dressed at a later stage.

The first two objectives of the EU's adaptation strategy for the rail sector - "Smarter adaptation" and "Faster adaptation" - must feed off each other. It was therefore crucial to draw up an overview of the study, clarifying its framework. This took the form of a flowchart shown in Fig.1.

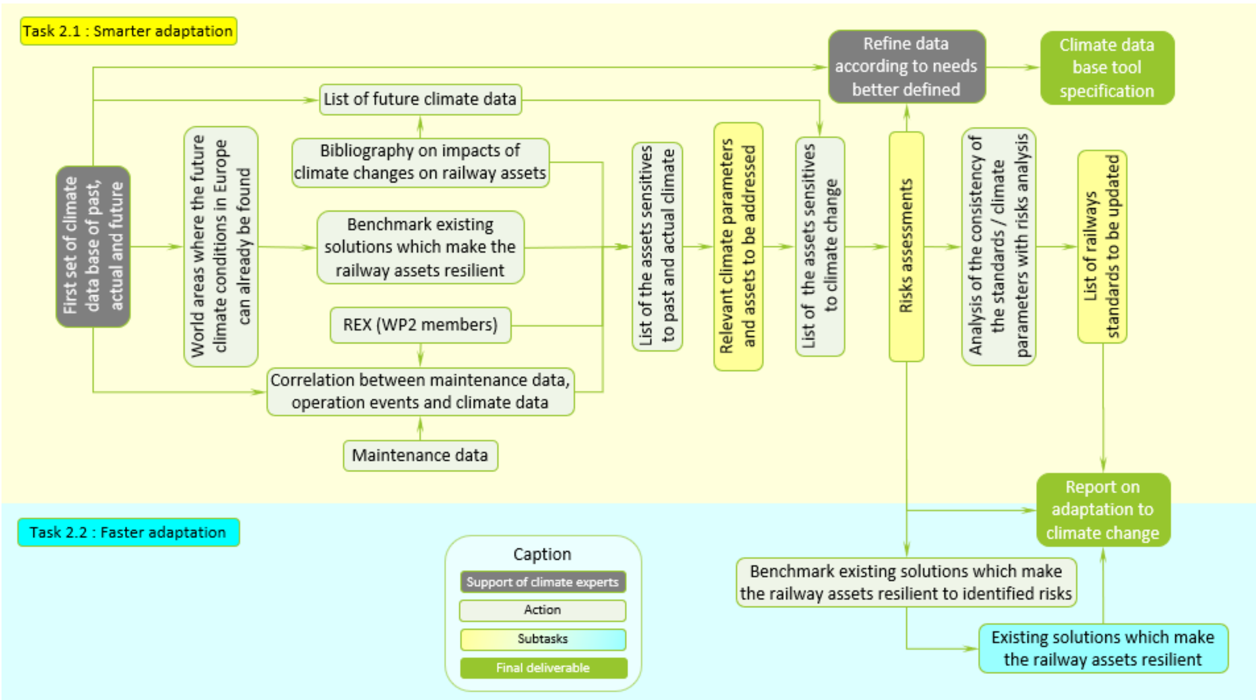

Fig. 1. Flowchart agreed within FP4-Rail4EARTH WP2 – Adaptation to climate change.

III. Smarter adaptation

The objective is to develop knowledge on climate change adaptation related to the railway assets design in order to make them resilient to the predicted climate scenarios for the coming decades, as their life duration ranges from 40 years (trains) to 100 years (infrastructure).

The main expected results are to provide European rail sector with standards and tools to help them define their resilience strategy.

To achieve the main intermediate result of this objective, i.e. the "List of the assets sensitive to climate change", several subtasks illustrated in fig.1 were launched in parallel including: **state-of-the-art** gathering the tasks "REX (Return of Experience) of WP2 members", "Bibliography on the impacts of climate change on railway assets" and "**correlation between maintenance data, operation events and climate data**".

Fig1. shows that the **assistance of climate experts** is also required.

A. State-of-the-art

The state-of-the-art offers partners the opportunity to share knowledge, to open up reflections and to gather data to create references of technical solutions implemented, resilience assessment methodologies used, standards involved and weather-related failures that railway assets have already faced. It was compiled based on feedbacks from group members and open access information.

The news on websites - like the specialised rail media - is full of extreme weather events that have caused sometimes devastating damages to rail systems. This shows, if proof were still needed, that climate change is already having a significant impact on railway assets. And sometimes these events can turn tragic, like the derailment of a passenger train in Carmont (UK) in 2020 [5], due to debris on the track, washed out from a drainage trench after a heavy rain. It cost three people their lives.

Works in academic literature is mostly related to the infrastructure and meteorological conditions [6], [7], [8], [9], [10]. However, data on technical solutions are scarce.

This review of the state of the art in adapting rail assets to climate change has highlighted the urgent need to integrate advanced technical solutions to improve the resilience and sustainability of the rail network in the face of the challenges posed by extreme weather events.

The international, European, and national legislative review highlight the importance of integrating climate risks into the management of railway assets, drawing on legislative frameworks and sectoral initiatives. It stresses the need to adapt international directives to national contexts in order to strengthen the sector's resilience. Finally, it calls for close collaboration between the various frameworks to improve sustainability in the face of climate change.

All this legitimizes the relevance of the work undertaken through this project.

The assessment of climate databases is fundamental to strengthening the resilience and adaptability of the rail system to the impacts of climate change. It has highlighted three main types of climate databases: historical databases for fault correlation, short-term prediction databases for resilient operations, and climate change scenario databases for climate-resilient assets. However, the use of these databases in climate risk analysis requires a complete process of retrieval, processing, and exploitation.

These data sources and the inevitable processing required to make them usable will be taken into account as part of the development of an IT tool designed to provide climate parameters applicable to European rail activities in categorised areas, taking into account the IPCC scenarios with statistics such as extreme values and standard deviations. This tool is intended to provide input for adaptation strategies in the European rail sector.

The identified existing Risk assessment methodologies suggest the adoption of a unified methodology for rail infrastructure and stations, due to their static geographical position which facilitates the prediction of exposure to climatic risks. Rolling stock, which traverses vast territories, requires a separate approach due to its unique risk assessment and adaptation planning challenges.

This developed knowledge will be used to provide risk assessments with the intention of developing the quantitative approach (e.g., determination of vulnerability thresholds) which is lacking.

The summary of the data collected on the three types of assets has highlighted the importance of adapting and strengthening the resilience of rolling stock to the challenges posed by climate change. It has highlighted the types of failure and the mechanisms by which high temperatures, intense precipitation and other extreme climatic events affect train components. The adaptation of rolling stock, particularly to increasingly intense and frequent heat waves, is a key issue.

With regard to stations and infrastructure, this summary also highlighted the need to integrate adaptation into all stages of a building's life, to understand climate risk data and to consider nature-based solutions, while ensuring adequate funding.

More specifically with regard to infrastructures, this summary highlighted the importance of an adaptation and resilience strategy in the face of climate change, combining temporary and definitive actions, such as reinforcing infrastructures, improving the availability of climate data and raising stakeholder awareness. It identifies the most important climate-related risks to railway infrastructures encompass flooding, landslides, rail buckling, bridge scouring, signalling failures, and drainage issues. Specific resilience measures are proposed, such as improving climate forecasts and technical studies on the resistance of materials, as well as identifying existing solutions for faster adaptation.

B. Correlation between maintenance data, operation events and climate data

1) Scope and approach description

The effects of climatic conditions on assets can be divided into three categories:

- Effects that have already (by now) caused major asset failures, climate change will only make things worse.
- Effects which are already appearing sporadically and have caused minor asset failures - often resolved by curative maintenance and not identified as a consequence of climate hazards - but which will become major with climate change.
- Effects that are not yet apparent but will become apparent with climate change.

Correlation between different databases aims to trap the second category.

As part of its corporate policy, the SNCF Group organised a Datathon (a Hackathon-type event dedicated to data processing) held in October 2023. A use case (UC) on Adaptation to Climate Change was included in this two-day event aimed at finding correlations between weather events and rail operating incidents/maintenance data by designing a data tool to allow these correlations to be fed by various data sources.

Data sources collected are shown in the Fig. 2. Here are their descriptions:

① weather data from MétéoFrance (SNCF Group has a dedicated contract with this French National Company).

② maintenance data from maintenance database called OSMOSE, including the designation of maintenance tasks, parts replaced and labour time. Only corrective maintenance has been considered.

③ on-board train network data from MyTrainData, which may be error codes or events recorded by on-board sensors. These data are stored in SNCF-Voyageurs' data lake.

④ incidents recorded on French railways from the Bréhat database, including the loss of operating time they caused. Only incidents where weather conditions have been identified as having had an impact on their occurrence.

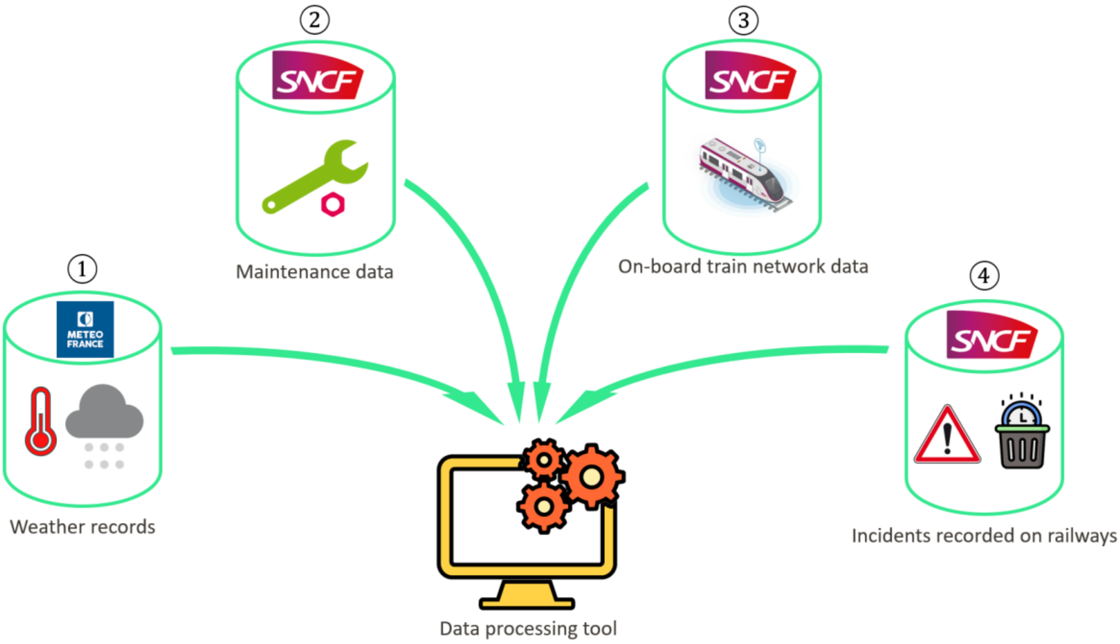

Fig. 2. SNCF Datathon 2023 – UC ACC: Data sources used for the data processing.

The big challenge was the short time of such an event. Two days, it is very short, and this ACC topic is very broad, it is why it was necessary to downsize the scope of this study defining some restrictions as shown in the Fig.3.

Fig. 3. Necessary restrictions applied to reduce the scope of the study.

Only the Ile de France Region was taken into account, i.e., public transport with only its two most connected trains (on-board network): Francilien (NAT) and Regio2n (original design by Bombardier Transport).

The considered period of the year was also reduced from May 15 to September 15 for the last 5 years as it was decided to focus on heatwaves and heavy rains (storm).

Although the restrictions were applied, the mass of data present was still too large to be compatible with the event format. This was particularly the case for data from onboard rail networks.

A recording file for a single train over the course of a day can contain up to 20,000 events, mainly commands or sensor states representing normal operating conditions (e.g., door open command and activation of limit sensors). Error codes representing malfunctions are also recorded, such as the failure of an air-conditioning unit. For each of these events, dozens of contextual data items (location, supply voltage, coupled train, etc.) are recorded. This data represents 95% of the total file size.

It has been necessary to process them in order to retain only those deemed suitable for a rapid understanding of the event to which they relate.

Even if the two days of the Datathon event did not allow us to begin a real phase of analysis of events trapped by the correlation, it is also always possible to return to all the context data in re-interrogating the source files (use of event code IDs).

2) Results:

Two multidisciplinary teams took part in the event. They were made up of business experts, data enthusiasts from across the SNCF group and data science students. In a competitive situation, the two teams exported two different approaches.

a) Team 1 – « Method of using return of experience »:

The team drew on an event that occurred on the morning of June 4, 2021, in operation, when almost half of the Francilien train fleet was affected by a failure of their auxiliary voltage converter (CVS AUX), leaving them inoperative.

The failure occurs when heavy rainfall causes water to infiltrate an electrical connector, resulting in electrical faults in the power converters (short circuit).

June 4, 2021 was a loud signal. This type of failure has also occurred on around 2 to 3 trains a year, revealing the existence of weak signals.

Team 1 tried to show that this type of event could be distinguished by cross-referencing meteorological and rolling stock data. By using mass data processing software (Databricks), it was possible to identify the event as shown in Fig.4.

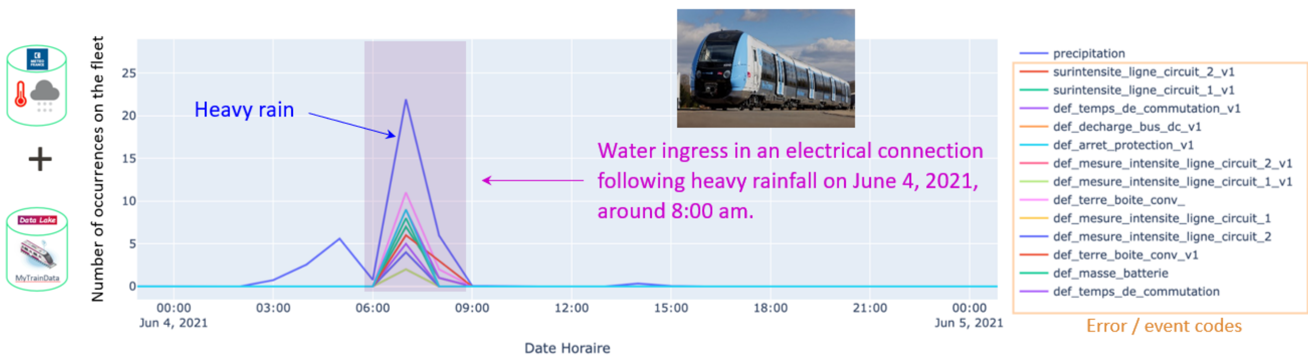

Fig. 4. Correlation between the Francilien error codes and the heavy precipitation of June 4, 2021.

Having processed data for the month of June 2021 alone, the team also attempted to find correlations between any weather parameters and any events recorded on the train's on-board network. A statistical processing model was used. As shown in Fig.5, for this month alone, a correlation seems to be emerging between an event code and the outside temperature.

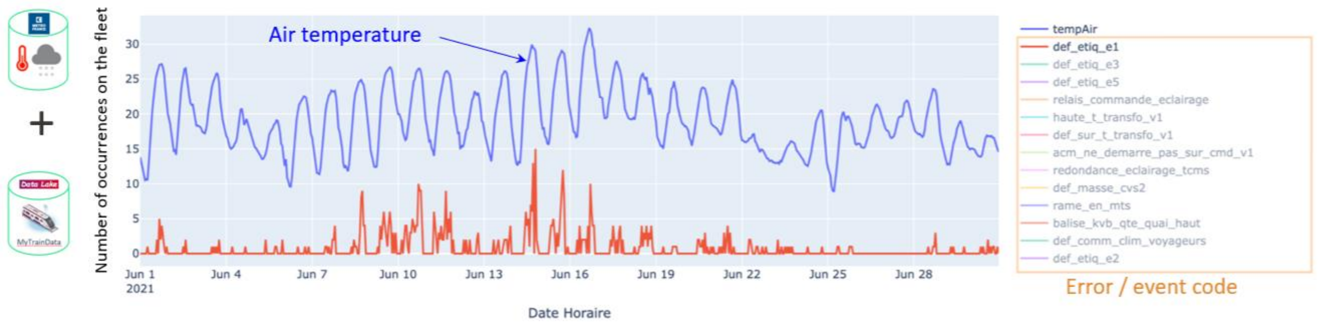

Fig. 5. Correlation between the Francilien error codes and the air temperature in June 2021.

b) Team 2 « Apriori-free method »:

With no preconceived ideas (no knowledge of specific feedback), this team tried to make all the data sources speak for themselves, using a machine learning model in particular.

As shown in Fig.6, a good correlation was found between the outside temperature and the occurrence of operational incidents. There is even a trigger temperature threshold of around 32°C.

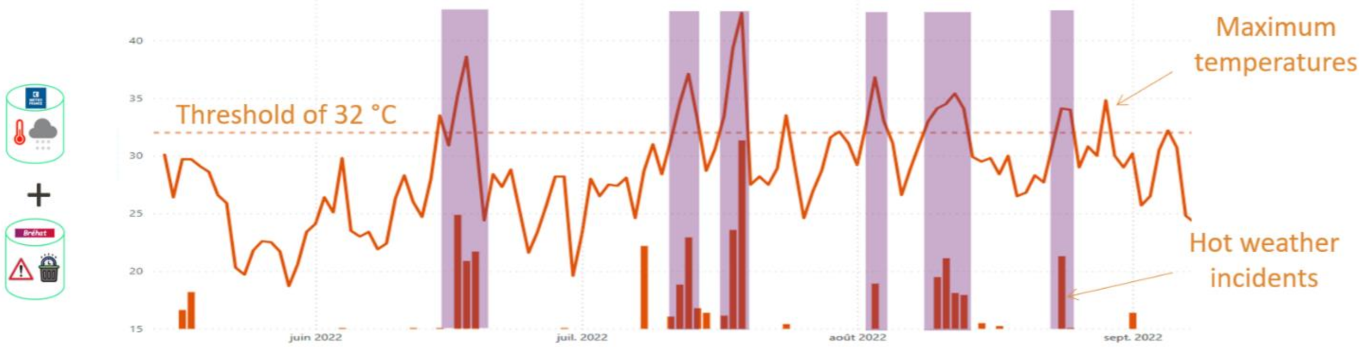

Fig. 6. Correlation between air temperature and hot weather incidents in operations.

Even without a direct correlation with weather data, the team was able to highlight the seasonality of corrective maintenance interventions on air-conditioning equipment. As shown in Fig.6, taking into account average monthly working hours, we can see that this maintenance extends from April to September.

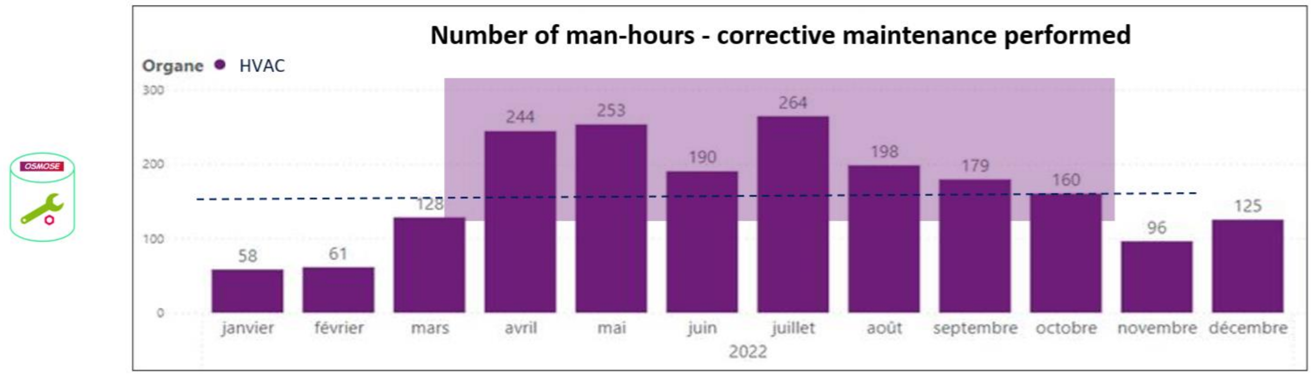

Fig. 7. Correlation between man-hours in corrective maintenance and extended season.

3) *Conclusion and outlook:*

Given the teams' start-up time, and the pitches to be prepared and led, no more than a day and a half was actually devoted to data manipulation.

Even over such a short period, and despite the fact that the two teams used different approaches, the results are promising and show that this type of data reconciliation will also be relevant and decisive in assessing the vulnerability of rolling stock.

As shown in Fig.8, less than 6% of the data from the on-board network of SNCF trains was made available for the Datathon. Of the 10 meteorological parameters of the MétéoFrance contract, only two of them were mainly used during the Datathon.

SNCF-Voyageurs therefore has huge potential data to exploit in order to characterize the vulnerability of its rolling stock in a robust way.

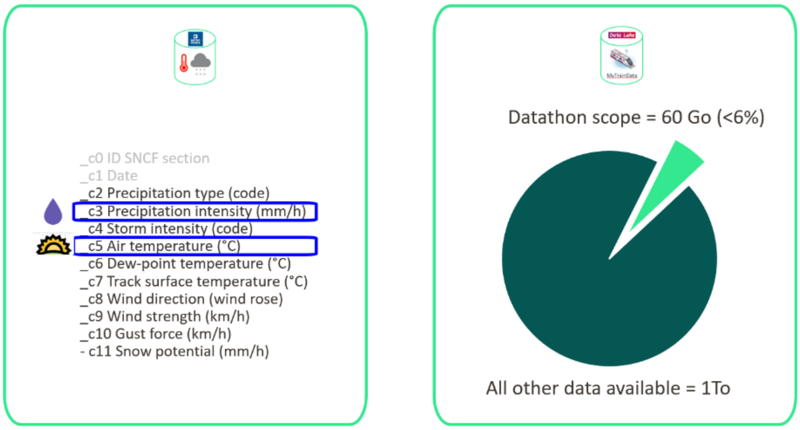

Fig. 8. Huge data potential to be exploited.

As with rail infrastructure assets, it is now clear that this type of approach is also relevant for rolling stock. The task now is to structure an internal project at SNCF-Voyageur to continue what was initiated during the Datathon: to develop and validate the tools and methodology with a view to implementing them at the various SNCF-Voyageurs rail operators.

C. Climate experts' assistance

The first exchanges of information within the group of European railway experts have revealed that the railway sector, like many other industrial sectors, deplores the lack of sufficiently relevant climatic data to guide their technical choices in terms of adaptation of their assets.

Past, present, and future climate data are available, often in open-access, but they are too global to be used to design assets and/or define their specifications and functionalities.

For instance, knowing the number of days over the next few decades when the temperature will reach over 45°C in large areas of Europe is useless to consciously decide on the specifications and degraded modes of an air-conditioning system appropriate to future climate change.

The number of days with a temperature between 35°C and 40°C, between 40°C and 45°C and between 45°C and 50°C and so on, according to various IPCC scenarri, in geographical areas corresponding to distinct mission profiles in terms of railway applications would be much more insightful.

Exploiting raw climate data is a task that needs expertise in climatology.

In order to be used by industrial sector, these data must be processed by climate experts. Such an expert profile is nowadays absent from the staff of railway companies. Finding competent climate experts, capable of providing accurate and relevant statistics on the identified climate parameters, is also a task to be accomplished as part of this study.

IV. Faster Adaptation

Current geographical areas in the World are certainly currently facing the future climate conditions of Europe: the technical solutions already implemented for railway activities will be benchmarked.

The aim is to define geographical zones corresponding to distinct mission profiles in terms of railway applications, to determine future climatic conditions in these zones and to identify the regions of the globe where it is possible to encounter such climatic conditions today. For all these aspects, the help of climatology experts is needed.

V. Results expected in 2024

Follow up the Datathon by structuring and launching an internal SNCF project to industrialise the promising approach developed during the event.

Panel of climate experts available on the market: it is expected to map the possible offers and their level of adequacy with the needs of the rail sector.

Risk assessment: identify the assets sensitives to climate change, using risks analysis studies, define acceptable nominal and degraded modes of the assets, according to climate events statistical occurrences, evaluate the impact of these modes on design, maintenance and operational rules and related costs.

Identification of technical solutions already implemented in the regions of the world concerned: international benchmark to be launched with a specialist company.

VI. Conclusion

This work is part of the FP4-Rail4Earth project, which aims to strengthen the resilience of Europe's railway sector to extreme weather events that increasingly threaten the stability and safety of rail operations.

Railway assets are increasingly vulnerable to extreme weather events, leading to operational disruption and significant material damage, such as derailments due to landslides and flooding, or structural failure of bridges due to foundation erosion.

The objective of this study was to establish a common and shared knowledge base of existing measures and methodologies to mitigate the risks posed by the intensification of climate extremes, focusing on the assessment of climate-related risks in the rail sector and supporting proactive measures to build resilience.

The methodology adopted is based on a broad sharing of knowledge within the consortium. The companies collected, shared and compared existing knowledge on assessment tools and adaptation solutions. This knowledge was acquired through literature reviews, detailed presentations of feedback and internal initiatives by the companies in the consortium.

The results of the analysis of this knowledge base have highlighted the need to carry out vulnerability studies for all railway assets. As far as rolling stock is concerned, adapting it to heat waves is a priority. The technical solutions envisaged (cooling systems with improved performance) must ensure that (thermal) comfort is maintained on board and that rolling stock remains available. Stations, especially those located in urban areas, must integrate adaptation throughout the life cycle of their buildings (e.g. low-permeability materials) and consider solutions based on nature (e.g. vegetation). Because of their configuration, stations share many of the same characteristics (buildings) as infrastructures, it is natural to find the same solutions, such as the need to deploy advanced technologies for their monitoring and management, including early detection systems and modelling tools to anticipate the impacts of climate change and plan interventions accordingly. For infrastructure, there is also the need to use more resistant materials, to design structures capable of withstanding higher temperatures or more intense rainfall, and to install water management systems (drainage). It is important to emphasise the limitations of vulnerability studies, in particular their dependence on available climate data and the complexity of accurately modelling future impacts on rail infrastructure.

This work has identified the pre-existence of methodological tools that enable evidence-based decision-making and strengthen the resilience of rail infrastructure and operations to climate change. This evidence can be provided by a robust and relevant approach to the correlation between maintenance data, operational events and climate data.

This study serves as a solid basis to guide future research decisions and ultimately develop the tools and methodologies needed to prioritise adaptation actions, taking into account trade-offs and involving relevant stakeholders in the decision-making process.

Through the various tasks and sub-tasks of this project, which will benefit from the results of this study, it is proposed to continue research in this area, focusing on the development of climate change prediction tools and risk assessment specific to the rail sector, in order to further improve the resilience of the European rail system.

REMERCIEMENTS

This work is part of the European research project for a sustainable rail system with acronym FP4-Rail4Eearth – received funding from the European Union’s under grant agreement No. 101101917.

REFERENCES

1. UNFCCC (United Nations Framework Convention on Climate Change), The Paris Agreement – Article 2 - paragraph (a), https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf, last accessed 2023/12/26.
2. IPCC (Intergovernmental Panel on Climate Change), AR6 Climate Change 2021: The Physical Science Basis - Chapter 4: Future Global Climate: Scenario-based Projections and Near-term Information, https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf, last accessed 2023/12/26.
3. EPRS (European Parliamentary Research Service), Sustainable and smart mobility strategy January 2021, https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/659455/EPRS_BRI(2021)659455_EN.pdf, last accessed 2023/12/26.
4. European Commission, EU Adaptation Strategy, (2021), https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en, last accessed 2023/12/26.
5. RAIB (Rail Accident Investigation Branch) Rail Accident Report, Derailment of a passenger train at Carmont, Aberdeenshire 12 August, 2022, https://assets.publishing.service.gov.uk/media/62275094e90e0747ae239cf4/R022022_220310_Carmont_High_resolution.pdf
6. Attoh, E., Goosen, H., Van Selm, M., Boon E., Ludwing,F.: Climate services for the railway sector: A synthesis of adaptation information needs in Europe, Frontiers in Climate (2022), https://doi.org/10.3389/fclim.2022.968298
7. Palin, E. J., Stipanovic Oslakovic, I., Gavin, K., & Quinn, A. (2021). Implications of climate change for railway infrastructure. Wiley Interdisciplinary Reviews: Climate Change, https://doi.org/10.1002/wcc.728.
8. Ochsner, M., Palmqvist, C.W., Olsson, N., Winslott Hiselius L. (2023), The effects of flooding on railway infrastructure: A literature review. In Transport Research Arena (TRA) Conference 2022 (Lisbon), https://doi.org/10.1016/j.trpro.2023.11.654
9. Greenham, S., Ferranti, E., Quinn, A., Drayson, K. (2020). The impact of high temperatures and extreme heat to delays on the London Underground rail network: An empirical study, https://rmets.onlinelibrary.wiley.com/doi/10.1002/met.1910
10. Ochsner, M., Ivina, D., Palmqvist, C. W. (2023), Weather-Related Railway Infrastructure Failures in Sweden: An Exploratory Study, https://lucris.lub.lu.se/ws/portalfiles/portal/141582044/Ochsner_et_al._Weather_Related_Railway_Infrastructure_Failures_in_Sweden_An_Exploratory_Study.pdf
11. Augusteijn, N., How tinted windows can help keeping trains in service in hot weather, Railtech, 2022, https://www.railtech.com/rolling-stock/2022/12/16/how-tinted-windows-can-help-keeping-trains-in-service-in-hot-weather, last accessed 2023/12/26.

1