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European Rail Network and Mobility Management

Deliverable 13.1
Use case specification and requirement specification for disruption management

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1. Executive Summary

This deliverable analyses the main use cases for disruption management within the context of railway infrastructures. Within the context of the WP10, each partner has described a set of use cases and disruption management in the case of railway infrastructures, which contributed to the writing of deliverable 10.1, which contains a high-level description and requirements. The D10.1 has been used as the starting point for further analysis, and the resulting use case description work in WP13 is documented in this D13.1. A detailed analysis and description of each use case is done for each use case, including the involved actors, pre-conditions and post-conditions, interactions for use case implementation, the exchanged data structures, and a table of the functional and non-functional requirements. The use cases and the relative analysis represent a detailed study in addition to D2.3 and D10.1 and belong to the Technical Enablers (TE) 11, 13, and 14:

- TE 11—HMI for TMS based on User Experience (UX) Design and user input: The development of an HMI solution for the railway sector must consider UX design principles to reduce the workload imposed on operators when dealing with critical actions, decisions and alarms in control centers when managing disruptions and critical tasks.
- TE 13—Cooperative planning multi-actors within rail: Critical events and alarms occurring along a railway are not handled by a single operator but by many of them, who should be able to communicate effectively with each other and with other stakeholders, including emergency responders, to ensure that the incident is handled appropriately.
- TE 14—Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management: Incident management in railway systems is a complex and challenging task that requires the skills and expertise of operators in control centers as well as many details and data to support the problem identification process, which calls for more integration of all the possible information sources.

The requirements elicited within these detailed use cases represent a specialization of the high-level requirements for the mentioned TEs. This document defines the input for the demonstrators to finalize disruption management. Based on these use cases, in D13.2, the design of HMI and the development of DSS for disruption management also describes the implementation of the DSS and HMI for disruption management. These components will be used in WP14 for the planned demonstrators, which HACON, STS, and TRV will mainly do. The planned demonstrators have been briefly described in D10.1 as follows:

- Demo 10 - Collaborative DSS for efficient and effective disruption management (STS, TRV, NSR, HACON): This demo is divided into three parts: one to be done by HACON, one by STS, and the last by NSR. In the first part, the demonstrator provided by HACON shows how collaborative decisions can be considered as resulting from decision support modules of TMS. In the second part, the demonstrator by STS shows how a DSS can support the operators when performing complex procedures to reduce the workload and fatigue in critical scenarios by providing suggestions to optimize maintenance, using information from IAMS concerning current traffic status, and implementing multi-actor coordination. The last part, written by NSR, deals with solving conflicts in rolling stock circulation, which may cause disruptions, minimizing impact on the operator and passenger sides.

- Demo 11 - HMI for TMS based on User Experience (UX) Design and user input (TRV, STS, INDRA): The HMI solution will be tested in a simulated environment when handling complex disruption management events to measure KPIs for situation awareness and mental workload.

The use cases presented in this document comes from the past and existing experiences of the partners, which will be used to design and realise the demos in WP14. In the meanwhile, this work is carried out, there are two other related works in parallel, the glossary of actors and their relationships in Deliverable 2.3 and the definition of the RCA architecture by SP. The contributors to this deliverable considered the glossary in D2.3 when writing this document; however, as at the time of writing this document, the RCA architecture from SP [RCA] was not stable neither distributed among the partners, it has not been considered as one of the input documents for the work described in this deliverable, leaving only D2.3 ad D10.2 as the starting points for this work. Certain use cases might be translated in this architecture without any efforts, while others require considerable efforts to exploit this architecture. We leave open the possibility for WP14 participants of considering and exploiting this architecture in the future work to be done in defining and realizing the planned demos, as well as in the next waves of the MOTIONAL project.

2. Abbreviations and acronyms

Abbreviation / Acronym	Description
CM	Capacity Management
CMS	Capacity Management System
CSM	Common Safety Method
DSS	Decision Support System
HMI	Human Machine Interaction
IL	Integration Layer
JIT	Just-In-Time
MAWP	Multi Annual Workplan
MM	infrastructure Maintenance Manager
MPS	infrastructure Maintenance Planning System
OCC	Operations Control Center
PFA	Preventive Functional Assessment
REA	Risk Evaluation and Assessment
RUD	Rail Wagon Unloading System
SAM	Semi-Automatic Mode
TC	Train/Traffic Controller
TCR	Temporary Capacity Restrictions
TE	Technical Enabler
TM	Traffic Management
TMS	Traffic Management System
UX	User Experience
WP	Work Package

3. Background

The present document constitutes the D13.1 “Use case specification and requirement specification for disruption management” in Flagship Project 1 – [MOTIONAL] as described in the EU-RAIL MAWP. D2.3 represents this document's input and starting point, “Use Cases for Planned Technical Developments of the Project,” which contains the high-level use cases for all planned technical developments. The current D13.1 starts from the requirements of D2.3 and improves the description and analysis of the use cases. Table 1 shows the mapping of the use cases in this document with the ones in D2.3. Moreover, high-level designs and Technical Enablers are described in D10.1, “Mapping against scope, high-level use cases, high-level requirements, high-level design for demonstrators”, which is also an input for the work described in this document and summarises the technical experience and competences achieved by previous international projects dealing with TMS development and integration and the trends of the market for such type of projects. This D13.1 also relates to D10.2, “Definition of Data elements.” Specifically, the description of the exchange data instances is briefly described in this document, while a more detailed and precise description and analysis is left to D10.2, where a detailed data model is presented by indicating entities, properties, and relationships among them. These use cases are used as the basis for the definition of the demonstrators in D14.1, and some of the requirements listed in this current report, D13.1, will be covered in those demos. D14.1 will explain which requirements will be covered and why some have been excluded from the demonstration.

The present document contains several use case specifications and the requirements for the DSS for disruption management and is organized in the following sections and related content:

Section	Content
4	Described the approach followed to write the deliverable
5	Defines the main use cases for disruption management. Each analysis contains a description of the use case, actors involved in the use case, their interactions, pre-conditions and post-conditions for the use case implementation, the data instances exchanged during the use case execution, and the requirements that the planned demonstrators within WP14 should satisfy are covered too
6	This section contains final conclusion related to the use cases and requirements analysis done
7	It reports references to be considered.

One denominator for the use cases defined here is the information interchange between human and technological actors, i.e., focusing on the interchange and interaction. One well-used definition of a *Human-Machine* Interface (HMI) perspective is *the interplay between people and machines (e.g., information technology, automation, robots, and intelligent interfaces)*. From a global pragmatical perspective, it aims to improve the relationship between people and technology and fosters positive social change, often, but not necessarily, through technology. Specifically, HMI Design refers to the design and layout of the interface through which humans interact with machines or systems. Such a design should be intuitive, user-friendly, and able to cope with effective communication and interaction between users and technology, especially in the railway sector and managing disruption where a significant workload is placed on the various involved actors. In such a design, User Experience needs to be correctly accounted for by considering the needs and expectations of users to help enhance usability, satisfaction, and productivity while reducing errors and learning barriers. Starting from the use cases defined in this report, in the next deliverable, D13.2, the methodology described for the design of HMI and development, as well as the implementation of DSS for disruption management, will be defined and tested during the demonstration to be presented in D14.1.

4. Objective/Aim

This report will specify the use cases and requirements for the DSS for disruption management with more details than what is described in D2.3 and D10.1 to be a useful input for D13.2 and the demonstrator's implementation and execution within the rest of WP13. The work described in this report are the result of the activities conducted within the context of tasks 13.5 and 13.6. The presented analysis will be an input for the next activities and for D13.2. Furthermore, a decision on the features and requirements of each use case will be made to design, implement, and execute the planned demonstrators.

4.1. Methodology

The methodology consisted of collecting use cases from all the partners participating in the WP13, and specifying for each of them the involved actors, the occurred interactions, and the exchanged data instances, according to the high-level specification in D2.3 and D10.1. The description provided by the partners has been compared with what has been written in D2.3 and D10.1 and possible mismatches have been identified and resolved. Moreover, in the description of each use case, we have considered the actors and their relationships as modelled in deliverable D2.3, which is expected to be in line with the modelling work undergoing in SP. At the write of this document, we did not have access to specific documents on SP actor modelling, so we have not considered it, leaving to the next deliverables to might apply such a model for the actors and responsibilities with respect to RCA architecture.

Afterward, all the use cases were analysed to find possible commonalities and reduce their number by aggregating those similar ones into a more generic one. Similarly, for each use case, a set of requirements has been elicited, by considering functional and non-functional features underlying them. The starting point for such an elicitation has been the set of high-level requirements specified for the Technical Enablers of reference for the use cases. Afterward, those requirements have been studied and refined into more generic ones to reduce their number. Each requirement has a severity degree associated with it (with a lower value equal to 1 to indicate low importance and negligible to be included in a demonstrator and the highest value equal to 5 for those requirements of higher importance to be included in a demonstrator). In D13.2 and later in the deliverable planned within WP14, we will describe which requirements will be excluded from the demonstration and the reason for such a decision. Each requirement is also classified into functional and non-functional, and a field 'Category' has been considered as a freestyle field. However, a typical category has been assigned to it using conventional taxonomies, such as the one in ISO/IEC/IEEE 29148:2018, when possible and suitable. Continuous interactions between the involved partners have been ongoing to contribute to the design and implementation of DSS for disruption management. Additionally, research on academic and industrial literature was conducted. It is necessary to improve the specification of the use cases and to have optimal coverage of the requirements for those systems.

5. Use Case Specifications

The following table summarises the use cases, which will be analyzed in detail in the subsequent chapters of the document. Table 1 shows the tasks involved in the study and, consequently, demonstrator design per use case. In addition, it also contains the mapping of these use cases, with the high-level ones from D2.3 and the Technical Enablers from D10.1. Specifically, the considered technical enablers:

- TE 11 - HMI for TMS based on UX Design and user input;
- TE 13 – Cooperative planning multi-actors within rail;
- TE 14 - Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management.

Use cases from participants to Task 13.1 for disruption management							
Use Case in D2.3	**Participant**	**Related to task**	**Impact on task**	**Name of the Use Case**	**Concise Description of Use Case**	**Technical Enabler**	**Demo**
UC-FP1-WP10-22	ADIF	13.5 (13.5.1), 13.2 (13.2.1, 13.2.2, 13.2.3)	13.6 (13.6.1, 13.6.3), 14.1	Disruption management and activation of emergency services	When a failure in the train or the trackside is detected, the system shows on the IM Operator's HMI information about the failure occurred, which is leading to the traffic disruption. Such information is acquired from TMS and/or sensors deployed at the assets. It is also indicated that an intervention is required, in particular, the need to activate emergency services/organisation.	TE 13, TE 14	10.1
UC-FP1-WP10-23	ADIF	13.5 (13.5.1, 13.5.3), 13.2 (13.2.1, 13.2.2, 13.2.3)	13.6 (13.6.1, 13.6.3), 14.1	Disruption management and activation of a maintenance intervention	When a failure in the train or the trackside is detected, the IM system shows on the HMI information about the failure occurred which is leading to the traffic disruption. It is also indicated that an intervention is required, specifically a maintenance intervention (needed resources (people), expected duration, impact on traffic…).	TE 13, TE 14	10.1
UC-FP1-WP10-18.1	HACON	13.5 (13.5.2), 13.2 (13.2.3)	13.6 (13.6.5), 14.1	Multi-actor coordination and decision support for implementation of aligned decisions	Options for changes of the Operational Plan for addressing incidents and related conflict scenarios are shared and commented on by multiple actors including responsible RU and maintenance staff (MMS Operator)	TE 13, 14	10.2
UC-FP1-WP10-18.2	HACON	13.5 (13.5.3), 13.4,	13.6 (13.6.5), 14.1	Show interaction of TMS with the Maintenance Planning System for	Collaborative decision making is shown for the case of urgent maintenance decisions triggering loops of alignment of maintenance	TE 13, 14	10.2

		13.2 (13.2.3)		improved and cooperative traffic optimisation and regulation	execution options with traffic replanning options to balance maintenance needs and resulting traffic impact.		
UC-FP1-WP10-18.3	HACON	13.4, 13.5 (13.5.4)	13.6 (13.6.5), 14.1	Give operational feedback to planning services to allow for improved timetable planning, as complementary activities to WP4/5	The importance of feeding TMS related operational information back to CMS capacity planning is shown with two major scenarios for communication of operational restrictions expected to last for multiple days (e.g., for covering needs of incident impact management) and observations captured by Traffic or Train Controllers to identify and overcome planning mismatches with knowledge about real operations.	TE 13, 14	10.2
UC-FP1-WP10-24	NSR	13.2 (13.2.4), 13.5 (13.5.1)	13.6 (13.6.2), 14.1	Solving of Rolling stock dispatching conflicts using reserves and swaps	Conflicts in the rolling stock circulation of a railway operator are usually solved manually. We aim to develop an algorithm that can automatically solve such rolling stock circulation conflicts that result from disruptions. The input is the actual rolling stock schedule, a disruption and the corresponding modified timetable. The output is the adjusted rolling stock schedule.	TE 14	10.3
UC-FP1-WP10-25	NSR	13.2 (13.2.4), 13.5 (13.5.1)	13.6 (13.6.2), 14.1	Proactive solving of macro tasks for crew dispatching	When conflicts in a driver/guard duty occurs, algorithms exist to help dispatchers solve these conflicts. Currently, these algorithms need manual triggering. We aim to move towards autonomous conflict solving by the system, under certain predefined conditions.	TE 14	10.3
UC-FP1-WP10-19	STS	13.2 (13.2.1, 13.2.5), 13.5 (13.5.1, 13.5.2, 13.5.4),	13.6 (13.6.1, 13.6.3), 14.1	Critical alarm management	The CTC System Operator is supported to reduce the effort and stress required to manage critical alarms, by providing through the HMI different type of help (suggestion, useful info...) and supporting the critical event resolution.	TE 11, 13, 14	10.1
UC-FP1-WP10-20	STS	13.2 (13.2.2), 13.5 (13.5.1, 13.5.2)	13.6 (13.6.1, 13.6.3), 14.1	Short-term management of a possible asset failure	The system receives monitoring information, determines if it is a symptom of an upcoming failure of an asset and evaluates which is the preferable time window in which to plan intervention and the kind of intervention	TE 11, 14	10.1

UC-FP1-WP10-21	STS	13.2 (13.2.2), 13.5 (13.5.2),	13.6 (13.6.1, 13.6.3), 14.1	Preventive Functional Assessment (PFA)	To cope with a lack of monitoring data for assets that are not used for a long period, preventive functional assessment needs to be conducted. The system continuously monitors the assets and support the CTC System operator in identifying such assets and suggesting when the PFA needs to be done rearranging the railway traffic accordingly.	TE 11, 14	10.1
UC-FP1-WP10-26	TRV/VTI	13.2 (13.2.1, 13.2.5), 13.3, 13.5 (13.5.4)	13.6 (13.6.4), 14.1, 14.2	Trespassing	Detection of one or more unauthorized persons entering the track area. Leads to a stop in traffic until the dispatcher is able to confirm that the track is clear (of obstacles).	TE 11, 14	11
UC-FP1-WP10-28	TRV/VTI	13.2 (13.2.1, 13.2.5), 13.3, 13.5 (13.5.4)	13.6 (13.6.4), 14.1, 14.2	Infrastructure problems detected by railway staff	The train driver (or other railway staff) notices something unusual and contacts the dispatcher. Depending on the information given by the driver the dispatcher has to decide if the traffic can go on and under which conditions.	TE 11, 14	11

Table 1 - Use case summary for TE11,13 and 14

5.1. ADIF Uses Cases

5.1.1. UC-FP1-WP10-22 - Disruption management and activation of emergency services

Use Case assumed by STS in its Demo 10.

5.1.1.1. Description

Through the monitoring of the state of the assets on the trackside, a partial or complete track blockage is detected, for example, caused by:

- Train failure
- Track failure (signalling system)

This may result in a traffic disruption (lesser or greater, depending on the speed in handling and decision-making). A warning alarm indication is activated in the system (failure of points, signals, track circuits, etc.), which must be managed. The system also shows on the IM Operator´s HMI information about the failure that led to the traffic disruption (useful information for the operator).

It is also indicated that an intervention is required in the HMI, particularly the need to activate emergency services/organisations.

The responsible operator managing the incident (namely, the Emergency Coordinator) coordinates emergency services. The coordinator may implement alternative transport to transfer passengers, a shuttle service, or a trailer train to help the train. However, the TMS operator usually coordinates and activates emergency services initially. Each IM has its own procedures.

5.1.1.2. Actors

- Railway Undertaking (RU): Public or private undertaking whose principal business is to provide services for transporting goods and/or passengers by rail with a requirement that the undertaking ensure traction; this also includes undertakings that provide traction only. (Directive 2012/34/EU). When there is traffic disruption, continuous communication and coordination between IM – RU may be required to find the best solution and manage the resources (trains and crew required).
- Infrastructure manager (IM) – IM operator: It is a body or firm responsible for establishing, managing, and maintaining railway infrastructure, including traffic management and control-command and signalling. It oversees the infrastructure capacity and traffic management. TMS in train control centers falls within the responsibilities of the IMs.
- TMS manager: The TMS manager is ultimately responsible for deciding which trains have priority in the event of conflicts and, therefore, which trains are penalized in their resolution.
- TMS operator: The TMS operator is responsible for supervising and managing the movement of the trains and ensuring the planned schedule is complied with according to the daily schedule. Also, it implements delay mitigation and emergency strategies and usually makes decisions to face traffic disruptions.
- Emergency coordination/emergency coordinator: Department or specific section coordinating emergency services (alternative transport to passengers, shuttle service, trailer train to help the train). The initial coordination and activation of emergency
- services are carried out from the TMS. Emergency Coordinator is the person who coordinates activities in emergencies (Incident Management).

5.1.1.3. Pre-Conditions, Inputs

- TMS monitors and manages the traffic and the signalling system from the control centres.
- TMS is capable of detecting (receiving the information from the monitoring of the sub-systems, signalling system, energy system, etc.), and informing real-time incidents in the sub-systems involved in traffic management. Management of alarm indications.
- Through the monitoring of the state of the assets on the trackside, a train failure or trackside failure (signalling system) is detected, leading to traffic disruption. The information is acquired from TMS and/or sensors deployed at the assets.
- The system receives an alert about the event as input.
- Multi-actor workflow, including decision negotiation and management.
- HMI is available to receive the reporting of information/suggestions.

5.1.1.4. Post-Conditions, Output

- The TMS operator can make decisions based on suggestions/information received. This helps to reduce the operator's workload, normally pending and involved in numerous activities at the same time, and greater immediacy in decision-making is achieved.
- Suggestions and indications are to be provided according to the importance.
- The TMS operator will receive indications of the need to activate emergency services (alternative transport to transport passengers, shuttle service, trailer train to help the train).
- Information is provided through the HMI. The information must be positioned so that it is visible and easy for the TMS operator to handle.
- Output: The decision to activate emergency services is made by the person responsible for managing the incident (alternative transport to transport passengers, shuttle service, trailer train to help the train).

5.1.1.5. Sequence

1. TMS monitors and manages the traffic and the signalling system from the control centres.
2. Monitoring the state of trackside assets provides the system/TMS with information about disruptions caused by asset failure (train or infra failure). Because of this, network traffic is interrupted. Data is received/collected from monitoring different subsystems (signalling system, energy, ETCS).
3. The TMS Operator received an alarm indication when monitoring the different systems.
4. The system shows the HMI to the TMS Operator information about the failure type.
5. The system shows through the HMI to the TMS operator info about the disruption if known (duration, train affected, section of the network affected, among others).
6. To help the operator make decisions, the System displays suggestions/proposals of steps to follow to mitigate/resolve the situation as soon as possible through the HMI.
7. The decision to activate emergency services is made by the responsible for managing the incident (alternative transport to transport passengers, shuttle service, trailer train to help the train).

5.1.1.6. Exchanged Data Instances

- Recovering data from train path monitoring (time control points audit) to detect deviations.
- Recovering data from sub-systems involved in traffic control to detect abnormal behaviour.
- Alarms with observation information from systems under active monitoring
- Remediation commands to actors for alarm management.
- Feedback on remediation effectiveness.
- Inform the operator through the HMI of detected incidents and possible solutions.

5.1.1.7. Requirements

Those defined in TE 13-14:

- TE 13: Cooperative planning multi-actors within rail [TRL4/5].

- TE 14: Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management [TRL4/5].

Requirement ID	Functional/ Non-Functional	Category	Description	Severity
UC-FP1-WP10-22_R1	Functional	Usability	The system shall provide indication on tasks and action responsibilities in complex procedures, to reduce the risk of misunderstanding between operators that may lead to undesired decisions, which can negatively impact beneficiaries' welfare	5
UC-FP1-WP10-22_R2	Functional	Usability	The system shall visualise all the relevant information, such as alarms, along with decision support tools and communications to help OCC operator to restore normal services quickly and safely	5
UC-FP1-WP10-22_R3	Non-Functional	Timeliness	The system shall provide real-time information about the status of the railway system	5
UC-FP1-WP10-22_R4	Functional	Usability	When disruption occurs, it shall support the involved operators in the problem identification process, providing detailed information about the disruption (such as, which is the exact problem/limitation in the network, its status, its direct consequences on the line/infrastructures and on the traffic condition...)	5
UC-FP1-WP10-22_R5	Functional	Usability	It shall support the operator during the management of anomalies or unexpected events, providing a transparent status overview of disturbance attributes in the system and their direct impact on the infrastructures capabilities (E.G. Overhead current group actions), the information on the correct actions to be taken and the support to implement them in the most effective way.	5
UC-FP1-WP10-22_R6	Functional	Usability	The system should be able to identify the causes of a disruption	5
UC-FP1-	Functional	Usability	It shall support the operator in the	5

WP10-22_R7			management of a critical situation, providing the list of actions of the procedure that must be performed (partially automatic);	
UC-FP1-WP10-22_R8	Functional	Usability	It shall provide recommendations, by proposing specific actions (but the actions remain in a manual mode, still in the hands of the operators);	5
UC-FP1-WP10-22_R9	Functional	Usability	To support the operator in solving a task, it shall extract and process all the useful information that are typically available, but difficult to be obtained and analyzed by the operator himself.	

Table 2 - Requirement table for UC-FP1-WP10-22

5.1.2. UC-FP1-WP10-23 - Disruption management and activation of maintenance intervention

Use Case assumed by STS in its Demo 10.

5.1.2.1. Description

Through the monitoring of the state of the assets on the trackside, a partial or complete track blockage is detected, for example, caused by:

- Train failure
- Track failure (signalling system)

This may result in a traffic disruption (lesser or greater, depending on the speed in handling and decision-making). A warning alarm indication is activated in the system (failure of points, signals, track circuits, etc.), which must be managed. The system also shows on the IM Operator´s HMI information about the failure that occurred, which led to the traffic disruption.

It is also indicated that an intervention is required, specifically a maintenance intervention (needed resources (people), expected duration, impact on traffic…). Maintenance action is triggered.

5.1.2.2. Actors

- Railway Undertaking (RU): Public or private undertaking whose principal business is to provide services for transporting goods and/or passengers by rail with a requirement that the undertaking ensure traction; this also includes undertakings that provide traction only. (Directive 2012/34/EU). When there is traffic disruption, continuous communication and coordination between IM – RU may be required to find the best solution and manage the resources (trains and crew required).

- Infrastructure manager (IM): An IM is a body or firm responsible for establishing, managing, and maintaining railway infrastructure, including traffic management, control command, and signaling. It oversees infrastructure capacity and traffic management. Traffic Management Systems (TMS) in train control centres fall within the responsibilities of IMs.
- TMS manager: The TMS manager is ultimately responsible for deciding which trains have priority in the event of conflicts and, therefore, which trains are penalized in their resolution.
- TMS operator: The TMS operator is responsible for supervising and managing the movement of the trains and ensuring the planned schedule is complied with according to the daily schedule. Also, it is the one who implements delay mitigation and emergency strategies and usually makes decisions to face traffic disruptions.
- MMS manager: Responsible for maintenance management using the Maintenance Management System (MMS).
- MMS Operator: A user of the Maintenance Management System (MMS).

5.1.2.3. Pre-Conditions, Inputs

- TMS monitoring and managing the traffic and the signalling system from the control centres.
- TMS capable of detecting (receiving the information from the monitoring of the sub-systems (signalling system, energy system, etc)) and informing real-time incidents in the sub-systems involved in the traffic management. Management of alarm indications.
- Through the monitoring of the state of the assets on the trackside, a train failure or trackside failure (signalling system) is detected leading to a traffic disruption. The information is acquired from TMS and/or sensors deployed at the assets.
- The system receives an alert about the happened event, as an input.
- Multi-actor workflow including decision negotiation and management.
- HMI available to receive the reporting of information/suggestions.

5.1.2.4. Post-Conditions, Output

- The TMS operator can make decisions based on DSS suggestions. This helps to reduce the operator's workload, normally pending and involved in numerous activities at the same time, and greater immediacy in decision-making is achieved.
- Suggestions and indications to be provided according to the importance.
- Information provided through the HMI. The information must be positioned in such a way that it is visible and easy to handle for the OCC operator
- Output: indications to the TMS operator with the need to activate the maintenance service.
- Output: Maintenance action is triggered.

5.1.2.5. Sequence

1. TMS monitors and manages the traffic and the signalling system from the control centres.

2. From the monitoring of the state of trackside assets, the system/TMS receives information about a disruption because of asset failure (train or infra failure). The traffic is interrupted in the affected section. The information is received/collected from the monitoring of different subsystems (signalling system, energy, etc).
3. HMI shows to the TMS operator info about failure and the proposal of steps which are needed to mitigate the problem.
4. DSS provides info of necessary maintenance tasks to mitigate the failure, including required resources (people, assets, ...), expected duration, impact on traffic…
5. Maintenance action is triggered.

5.1.2.6. Exchanged Data Instances

- Recovering data from train path monitoring (time control points audit) to detect deviations.
- Recovering data from sub-systems involved in traffic control to detect abnormal behaviour.
- Alarms with observation information from systems under active monitoring
- Remediation commands to actors for alarm management.
- Feedback of remediation effectiveness
- Inform the operator through the HMI of detected incidents and possible solutions.

5.1.2.7. Requirements

Those defined in TE 13-14:

- TE 13: Cooperative planning multi-actors within rail [TRL4/5].
- TE 14: Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management [TRL4/5].

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-23_R1	Functional	Usability	The system shall provide indication on tasks and action responsibilities in complex procedures, in order to reduce the risk of misunderstanding between operators that may lead to undesired decisions, which can negatively impact beneficiaries' welfare	5
UC-FP1-WP10-23_R2	Functional	Usability	The system shall visualise all the relevant information, such as alarms and CCTV feeds, along with decision support tools and communications to help OCC operator to restore normal	5

			services quickly and safely	
UC-FP1-WP10-23_R3	Non-Functional	Timeliness	The system shall provide real-time information about the status of the railway system	5
UC-FP1-WP10-23_R4	Functional	Usability	When disruption occurs, it shall support the involved operators in the problem identification process, providing detailed information about the disruption (such as, which is the exact problem/limitation in the network, its status, its direct consequences on the line/infrastructures and on the traffic condition...)	
UC-FP1-WP10-23_R5	Functional	Usability	It shall support the operator during the management of anomalies or unexpected events, providing a transparent status overview of disturbance attributes in the system and their direct impact on the infrastructures capabilities (E.G. Overhead current group actions), the information on the correct actions to be taken and the support to implement them in the most effective way.	5
UC-FP1-WP10-23_R6	Functional	Usability	The system should be able to identify the causes of a disruption	5
UC-FP1-WP10-23_R7	Functional	Usability	It shall support the operator in the management of a critical situation, providing the list of actions of the procedure that must be performed (partially automatic).	5
UC-FP1-WP10-23_R8	Functional	Usability	It shall provide recommendations, by proposing specific actions (but the actions remain in a manual mode, still in the hands of the operators);	5
UC-FP1-WP10-23_R9	Functional	Usability	To support the operator in solving a task, it shall extract and process all the useful information that are	5

			typically available, but difficult to be obtained and analyzed by the operator himself.	

Table 3 - Requirement table for UC-FP1-WP10-23

5.2. HACON Uses Cases

5.2.1. UC-FP1-WP10-18.1 - Multi-actor coordination and decision support for implementation of aligned decisions

5.2.1.1. Description

The demonstrator provides the technical basis for demonstrating how collaborative decisions can be considered as resulting from decision support modules of a TMS. The graphical user interface features Train Graphs, network views as well as train schedule details views. Since the system does not include a crew/rolling stock dispatching system, specific views emulating such a system are used to reflect the required changes of resource links as assigned to trains.

The goal is to test and demonstrate Use Cases related to multi-actor coordination and decision support for implementation of aligned decisions (TE13).

The demonstrated capabilities help to

- improve forecast calculation quality due to considered (collaborative) decisions based on constraints or needs of integrated processes/systems; and
- To optimize cost/benefit ratio of effective train operations resulting from aligned and fast decisions.

Demo scenarios covered:

- Changes of Crew/Rolling Stock links impacting the forecast result or triggering re-planning in TMS;
- Establishment of collaborative decision-making results by means of Control Rules.

5.2.1.2. Actors

- TMS: TMS System
- TC: Train/Traffic Controller using the TMS
- MMS: Maintenance Management System (IAMS in FP3)
- MMS Operator
- CMS: Capacity Management System
- CMS/CMS User

- RUD: crew/rolling stock dispatcher of a Railway Undertaking responsible for involved crew/stock resources

5.2.1.3. Pre-Conditions, Inputs

Input is represented by Baseline data: operational plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR).
Pre-conditions are the following ones:

- The TMS Forecast Window is 3-4 hours; plans are available for the next 7 days;
- An operational plan (7 days) for a smaller national or regional scope with mixed freight and passenger trains and capacity restrictions, calculated forecast for 3-4 hours;
- A set of active Control Rules reflecting earlier control decisions.

5.2.1.4. Post-Conditions, Output

Output is the following one:

- adjusted timetable suggested to the planner in the DSS subsystem for implementation adjusted or new active Control Rules and updated forecast / operational plan;
- multi-actor scenario that highlights the exchange of data occurring among these actors;
- calculated forecast considering collaborative decisions.

Post-condition is that collaborative TM decisions are implemented.

5.2.1.5. Sequence

1. Via the interface, the RUD introduces a new resource link (Crew or Rolling Stock) between two trains stopping at the exact location A reflects the re-use of the resource swapping the trains at that location.
2. TMS generates a Control Rule matching the new resource link with given parameters/conditions.
3. The first train faced a disruption, causing a major delay at station A.
4. TMS updates the train running forecast, showing major delays for the first train and, as a knock-on effect, also for the second train when departing from A. The delayed second train caused issues with other trains not affected so far.
5. The TC requests the RUD to improve the situation by reconsidering re-planning options on RU-side.
6. Via the interface, the RUD updates the resource link to let the second train go after a maximum waiting time threshold has elapsed.
7. TMS updates the Control Rule, reflecting the update of the resource link with updated parameters/conditions.
8. The first train is further delayed.
9. TMS updates the train running forecast indicating that the second train will depart at A without waiting for the first train since the maximum waiting time threshold of the Control Rule has been exceeded.
10. The other trains are not impacted anymore.

5.2.1.6. Exchanged Data Instances

- Operational Plan
- Train Running Forecast
- Resource Links (Crew / Rolling Stock)

5.2.1.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-18_R1	Functional	Usability	The system, if several operators with different roles are involved, shall provide integrated support in the managing of traffic after a severe perturbation.	4
UC-FP1-WP10-18_R2	Functional	Usability	The system helps to coordinate and to supervise multiple operators involved in the resolution of disruptive issues, to provide optimal solutions in complex scenarios.	4
UC-FP1-WP10-18_R 3	Functional	Usability	The system shall provide technical support for multi-acting, information sharing and negotiating among actors involved and/or affected. Technical Enabler 14: Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management.	4
UC-FP1-WP10-18_R4	Functional	Usability	When disruption occurs, it shall support the involved operators in the problem identification process, providing detailed information about the disruption (such as, which is the exact problem/limitation in the network, its status, its direct consequences on the line/infrastructures and on the traffic condition...).	4

UC-FP1-WP10-18_R5	Functional	Usability	The system shall provide recommendations, by proposing specific actions (but the actions remain in a manual mode, still in the hands of the operators).	4

Table 4 - Requirement table for UC-FP1-WP10-18.1

5.2.2. UC-FP1-WP10-18.2 - Show interaction of TMS with the Maintenance Planning System for improved and cooperative traffic optimisation and regulation

5.2.2.1. Description

The demonstrator provides the technical basis for demonstrating how collaborative decisions can be considered as resulting from decision support modules of TMS. A specific focus is set with respect to collaborative track maintenance decision making supported by interfaces with the IAMS/DMPS subsystem as implemented in FA3-IAMS4RAIL WP8/9. The graphical user interface will feature Train Graphs, network views as well as train schedule details views.

The goal is to test and demonstrate Use Cases related to

- multi-actor coordination and decision support for the implementation of aligned decisions (TE13);
- interaction of TMS with the Maintenance Planning System for improved and cooperative traffic optimization and regulation.

The demonstrated capabilities help to

- improve forecast calculation quality due to considered (collaborative) decisions based on constraints or needs of integrated processes/systems; and
- To optimize effective train operations' cost/benefit ratio resulting from aligned and fast decisions.

Demo scenarios covered:

- Maintenance plan updates requiring train regulation changes impacting the forecast result or triggering re-planning in TMS, e.g., due to results of measurement runs and re-prioritization of maintenance (FA3-IAM4RAIL WP8/9);
- Providing timetable information to maintenance planning (FA3-IAM4RAIL WP8/9) to align decision-making and minimize the impact of maintenance plans.

5.2.2.2. Actors

- TMS: TMS System
- TC: Train/Traffic Controller using the TMS

- MPS: infrastructure maintenance planning system
- MM: infrastructure maintenance manager

5.2.2.3. Pre-Conditions, Inputs

Baseline data represent input: operational plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR).
The pre-conditions are the following ones:

- The TMS Forecast Window is 3-4 hours; plans are available for the next 7 days.
- An operational plan (7 days) for a smaller national or regional scope with mixed freight and passenger trains and capacity restrictions, calculated forecast for 3-4 hours;
- Updates of planned infrastructure maintenance by IAMS/DMPS of IAM4RAIL (FA3), WP8/WP9 received via interface;
- A set of active Control Rules reflecting earlier control decisions.

5.2.2.4. Post-Conditions, Output

The post-condition is that collaborative TM decisions are implemented. The output is represented by

- multi-actor scenario that highlights the exchange of data occurring among these actors;
- calculated forecast considering collaborative decisions.

5.2.2.5. Sequence

The following is a typical situation in railway asset management and related maintenance management (IAMS4RAIL WP8/WP9). Due to the results of a measurement train checking the condition of tracks, a planned maintenance activity on a given track section must be urgently re-prioritized to be performed in the next 18 hours. After checking the availability of the maintenance team and material, the MM decides on a suitable time window that matches the asset management needs but interferes with traffic.

1. The MPS receives an accidental possession request.
2. The MM implements the new maintenance/repair activity in the maintenance plan managed by the MPS.
3. The MPS sends the related temporary capacity restrictions (TCRs) including track blockages and temporary speed restrictions for the next 4 days to the TMS/CMS.
4. The TMS/CMS receives the TCRs and introduces them into the operational/capacity plan.
5. The TMS updates the train running forecast, indicating the impacted traffic to the TC in real-time.

6. Due to the current delays already reflected in the operational plan, the TC asks for a slight shift in the activity's time by one hour to address most of the issues caused by the TCR in the operational plan on the actual day.
7. The TMS communicates the request back to the MPS.
8. After checking with the maintenance team, the MM shifts the maintenance activity by one hour for the actual day.
9. The MPS sends the updated TCR to the TMS/CMS.
10. For the remaining days, the CMS adapts the impacted planned train paths in the capacity plan based on the original TCRs, involving the RUs who have requested the paths.
11. The TMS/CMS receives the updated TCR and introduces the update to the operational plan.
12. The TMS updates the train running forecast, indicating that the traffic impact has been mitigated.

5.2.2.6. Exchanged Data Instances

- Operational/Capacity Plan
- Temporary capacity restrictions (TCR)

5.2.2.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-18_R6	Functional	Usability	The system, through the development of adapters and protocols, shall be able to forward the right data to the right actors.	4
UC-FP1-WP10-18_R7	Functional	Usability	The system shall provide real-time information about the status of the railway system.	4
UC-FP1-WP10-18_R8	Functional	Usability	The system shall improve digitalization of communications between parties involved (users).	4
UC-FP1-WP10-18_R9	Functional	Usability	It shall improve interaction of the TMS with the Maintenance System.	4

Table 5 - Requirement table for UC-FP1-WP10-18.2

5.2.3. UC-FP1-WP10-18.3 - Give operational feedback to planning services to allow for improved timetable planning, as complementary activities to WP4/5

5.2.3.1. Description

The demonstrator provides the technical basis for demonstrating how operational data can be fed back to capacity planning to improve the timetable/track capacity planning. This includes integrating the capacity planning system as provided by FA1-MOTIONAL WP4/5. Operational data considered for triggering plan improvements in the CMS are as follows:

- (A) Operational restrictions, e.g., track blockages, Temporary Speed Restrictions or routing restrictions, or
- (B) Operational observations, e.g., informing the capacity planners about regular mismatches with real operations, like a repeated mismatch of operational track usage with the planned track usage.

The goal is to test and demonstrate Use Cases related to

- give operational feedback to planning services to allow for improved timetable planning as complementary activities to WP4/5;

The demonstrated capabilities help to

- optimize cost/benefit ratio of effective train operations resulting from aligned and fast decisions and improved timetables.

Demo scenarios covered:

- Feeding back TMS operational information to CMS.
  - (A) Set up an operational restriction in TMS and communicate the resulting Temporary Capacity Restriction to CMS for re-planning of train paths for the next days.
  - (B) Entry of an operational observation at a specific track location to indicate regularly non-matching arrival tracks in the plan delivered by the CMS.

5.2.3.2. Actors

- TMS: TMS System (Traffic Management)
- TC: Train/Traffic Controller using the TMS
- CMS: CMS System (Capacity Management)
- CM: Capacity planner/manager using the CMS

5.2.3.3. Pre-Conditions, Inputs

The input is presented by Baseline data: Capacity plan (CMS), related operational plan (TMS), and microscopic infrastructure model, including planned or operational maintenance restrictions (TCR). The pre-conditions are the following ones:

- The TMS Forecast Window is 3-4 hours; operational plan(s) available for the next 7 days.
- An operational plan (7 days) for a smaller national or regional scope with mixed freight and passenger trains and capacity restrictions;

5.2.3.4. Post-Conditions, Output

The post-condition is that the feedback is provided, and the outputs are the following:

- Operational feedback is sent to the capacity planning/management system;
- Plans received from capacity planning/management are better adapted to operational needs.

5.2.3.5. Sequence

1. (A) A major incident causes an immediate blockage of a track section in TMS.
2. The TC creates an operational TCR to reflect a track section blockage and associated temporary speed restriction (TSR) on the neighboring track for ten days leading to conflicts with running and planned trains.
3. The TMS generates solution options for regulating today's trains conflicting with the TCR.
4. The TC accepts a solution and the TMS implements the Operational Plan change for today's trains accordingly.
5. The TCR is sent to the CMS to re-plan train services for the next ten days.
6. The CMS receives the TCR from TMS.
7. CP is starting to analyse the impact on planned trains for the next days.
8. CP is changing the capacity plan accordingly.
9. The CMS sends updated operational plans for the next seven days to TMS, including the change.
10. TMS introduces the change into the operational plans, mitigating the impact.
11. (B) The TC enters an observation assigned to a track at a station reflecting the non-matching arrival track for a train as seen in operations from the past two weeks.
12. The observation is sent to CMS to consider re-planning the track assignment for the train at the station for future capacity plans.
13. After talking to the responsible RU and station manager, the CP is changing the track for the given train at the given location in the capacity plan starting from tomorrow accordingly.
14. The CMS sends updated operational plans for the next seven days to TMS including the change.
15. TMS introduces the change into the operational plans, improving the quality.

5.2.3.6. Exchanged Data Instances

Operational plan:

- Train paths
- Temporary capacity restrictions (TCR)

- Observations

5.2.3.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-18_R10	Functional	Usability	The system, through the development of adapters and protocols, shall be able to forward the right data to the right actors.	4
UC-FP1-WP10-18_R11	Non-Functional	Timeliness	The system shall provide real-time information about the status of the railway system.	4
UC-FP1-WP10-18_R12	Functional	Usability	The system shall improve digitalization of communications between parties involved (users).	4

Table 6 - Requirement table for UC-FP1-WP10-18.3

5.3. NSR Uses Cases

5.3.1. UC-FP1-WP10-24 - Solving of Rolling stock dispatching conflicts using reserves and swaps

5.3.1.1. Description

The planning process at a railway undertaking consists of 3 phases: timetabling, rolling stock scheduling, and crew scheduling. All these phases are done sequentially and well before the day of operation. Decision support systems are available to optimize crew and rolling stock plans in terms of efficiency for the operator and attractiveness for crew and passengers. On the day of operation, unexpected disruptions can happen that require rescheduling of all resources. In this project, we focus on real-time rescheduling the rolling stock.

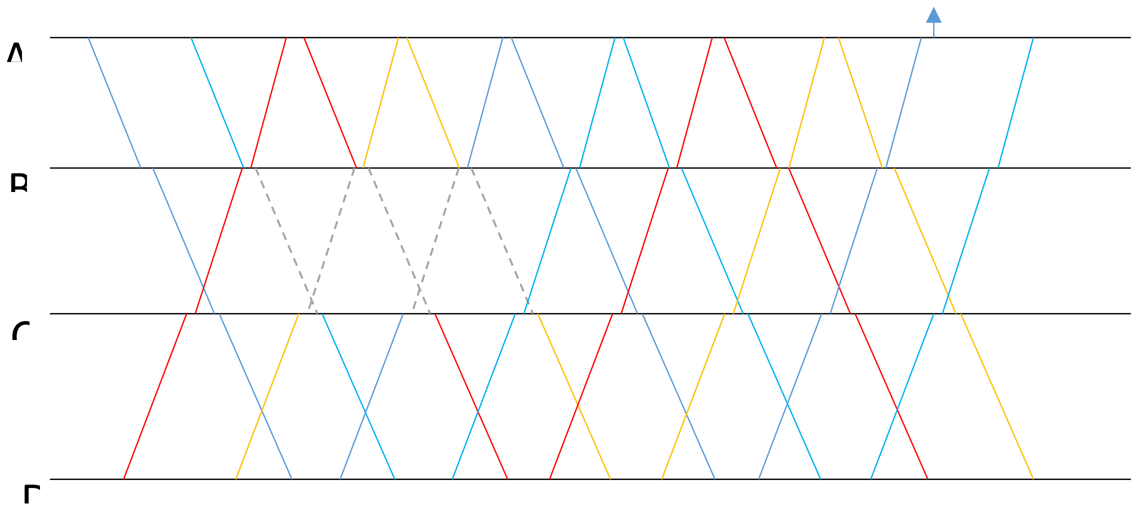

Figure 1Time-space diagram with the scheduled rolling stock plans

To get some intuition behind this use case, Figure 1 provides an example. In Figure 1, a time-space diagram is drawn, where the horizontal axis represents time, and the vertical axis represents the route among the stations A-B-C-D. Each line in the diagram represents a train trip in the timetable, while the coloring represents the rolling stock plan. Each color is an individual unit in the original plan. The dark blue arrow means the unit will be removed from the rotation and go to a maintenance facility. The dotted grey lines are canceled trips due to an unforeseen disruption between stations B and C. Finally, we assume here that dark and light blue represent a rolling stock type with 200 seats while yellow and red represent a different rolling stock type with 100 seats. As can be seen in Figure 1, the disruption leads to infeasibilities in the original plan; for example, the light blue unit was supposed to go from station A all the way to station D, but now this unit cannot continue after arrival in station B.

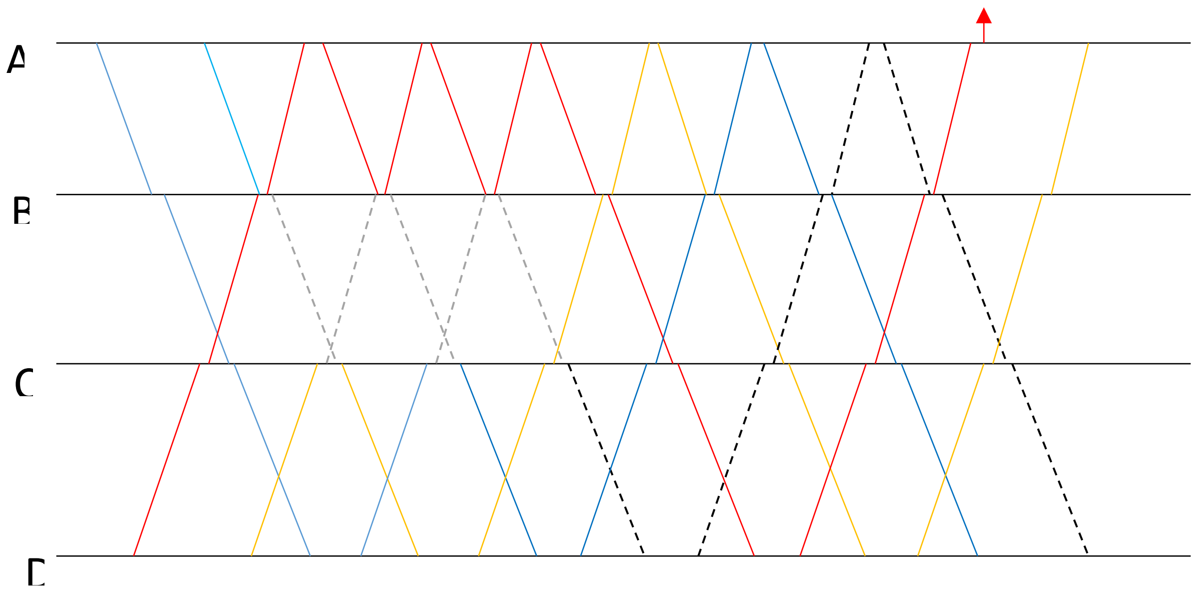

Figure 22Adjusted Rolling stock plan with short turnings at stations B and C

At most railway undertakings, predefined contingency measures describe how to handle disruptions. In most cases, this means arriving units at both sides of the disruption turn around as quickly as possible in the other direction. Figure 2 represents the new rolling stock plan after applying a contingency measure.
In Figure 2, we see how to reschedule the rolling stock plan during the disruption after the turn-around of rolling stock is applied. However, after the disruption ended and the normal timetable was in place again, the rolling stock plan was quite different from the original plan. After the disruption, the new rolling stock plan has several problems that a rolling stock dispatcher would need to repair, namely:

1) The dotted dark grey trips do not have any rolling stock assignment, while these trips should run as scheduled according to the timetable.
2) The dark blue unit should go to maintenance; however, the red unit ends up in the maintenance facility in the new situation.
3) In quite a few cases, the trips have fewer seats assigned than in the original plan. Depending on crowding prognoses, this could lead to a lack of capacity on some trips and major discomfort for passengers.
4) In the original plan, both blue units start and end at station A, while yellow and red units start and end at station D. In the rescheduled situation, this no longer holds, resulting in the need to reposition rolling stock during the night.

The focus is not on rescheduling the disruption itself (because this is done by precomputed contingency plans) but rather on the problems in the rolling stock rotation that occur in the hours after a disruption because of the disruption and the application of the contingency plans.
Large railway undertakings operate hundreds of rolling stock units, so it is not a trivial task for a rolling stock dispatcher to oversee all (future) consequences of a specific change in the rotation. For example, a shorter train is only a problem if the expected number of passengers exceeds the capacity for seats. Also, units of the same type are typically interchangeable, except when a specific unit is scheduled for maintenance soon. The decision support system should evaluate all units for the relevant time horizon and give feedback to the user on all detected conflicts in a real-time fashion.
The original rolling stock plan has some built-in slack to cope with disturbances in the form of reserve units. When reserve units are available, this is usually the most straightforward way of solving a problem. Detecting when and how an available reserve unit can be used effectively, considering constraints about coupling/shunting in an automated way, would be very beneficial in the rolling stock dispatching process. Swapping unit assignments, or combinations of multiple swaps, could solve problems, sometimes even without reserve units. Specific rules on what's possible and impossible at stations, platforms, and shunt yards must be considered to propose valid swaps.

5.3.1.2. Actors

- RU-Rolling stock dispatchers

5.3.1.3. Pre-Conditions, Inputs

Pre-condition: a disruption resulting in a modified rolling stock schedule has taken place.
Input: Actual rolling stock schedule, real-time traffic control data, crowding forecasts, and maintenance schedules.

5.3.1.4. Post-Conditions, Output

Detection of conflicts in current rolling stock rotation a few hours until a few days ahead.
Proposal to solve conflicts in current rolling stock rotation using a reserve unit or swap units.

5.3.1.5. Sequence

1) The algorithm detects all conflicts in the schedule and puts them in a list that is visualized to the rolling stock dispatcher.
2) Rolling stock dispatcher selects a conflict from the list
3) The developed algorithm calculates an effective solution to the conflict.
4) One or more effective alternative solutions are presented to the rolling stock dispatcher.

5.3.1.6. Exchanged Data Instances

The data consist of a rolling stock schedule in real time. This means the data contains an actual timetable and each rolling stock unit has a schedule. This means every rolling stock unit that is available has a duty that contains its current live location in the network and a planned set of tasks the unit is set to perform. A task is an object that reflects a piece of work for the unit, for example driving form station A to station B departing at time x and arriving at time y. Also, the task represents whether the unit is coupled to another unit or not, and if coupled the position of the unit is given in the task description.

5.3.1.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-26_R1	Non-Functional	Timeliness	The algorithm should have access to accurate and complete real-time data regarding rolling stock and timetable.	3
UC-FP1-WP10-26_R2	Functional	Usability	The algorithms should calculate a good solution in at most a few minutes.	5
UC-FP1-WP10-26_R3	Functional	Usability	The algorithm should provide a complete list of existing conflicts in the rolling stock schedule.	3
UC-FP1-WP10-26_R4	Functional	Usability	The system should calculate a score for each conflict.	3

Table 7 - Requirement table for UC-FP1-WP10-26

5.3.2. UC-FP1-WP10-25 - Proactive solving of macro tasks for crew dispatching

5.3.2.1. Description

Crew dispatching at NS is done using the CREWS-Real-time Dispatcher system (hereafter just system) provided by SISCOG. Several advanced decision support algorithms are available for dispatchers at a railway undertaking within the system. SAM (semi-automatic mode) is a fast, greedy heuristic based on the ideas of [Verhaegh et al. 2017]. It helps the dispatcher find solutions for a single unplanned task. Using SAM, an unplanned task can be rescheduled within seconds by only changing one or a few duties if a solution within the rule set of SAM exists. The JIT-solver (Just-in-time-solver), see [Morgado and Martins 2012], can reschedule dozens of duties at once in case of a medium-sized disruption, for example, when a part of the network is broken for a few hours. The JIT-solver combines column generation and Lagrangian relaxation with a large neighborhood search. Finally, the VLSR (very large-scale rescheduling), see [Fioole et al. 2019], can overhaul large parts (up to the entire schedule) in case of significant unforeseen events several hours in advance, or in case of preventive measures, for example, severe winter conditions. VLSR combines column generation techniques with a Lagrangian heuristic.

Even though these algorithms are successfully used in practice, much manual decision-making and preparation before a solver run are still involved. This limits the use and effectiveness of these algorithms to their full potential. We aim to add tooling and support to make the process even more automated and support dispatchers more effectively.
As mentioned before, the semi-automatic mode can solve a single unplanned task. The current process is as follows: First, a dispatcher removes a conflicted task from a duty, making the task unplanned. After that, the dispatcher can trigger the SAM algorithm with a few mouse clicks. If a solution (or a few options) is found, the dispatcher assesses this solution and approves one of them manually. Finally, the chosen solution is sent to the driver/guard. We envision moving towards a fully automatic mode, where one or more of the aforementioned manual steps will be automated.

Consider the example in Figure 3 where green tasks represent driving and yellow represents deadheading:

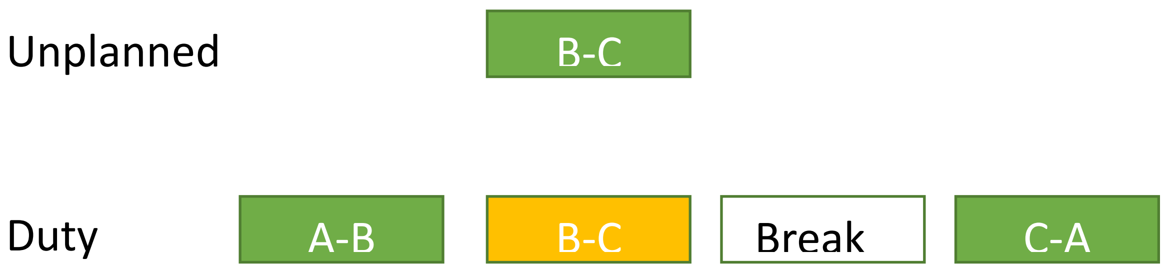

Figure 33xample of an unplanned task from B to C and a duty with a deadhead task from B to C

In this example, it is obvious that the deadheading task can be replaced by the unplanned task and thus solve the problem. Note, however, that duty X is among hundreds of other duties in the system, so it can be challenging for a dispatcher to see that this easy fix exists. Also, typically, there are multiple unplanned tasks. Current practice is that a dispatcher must decide which unplanned task to consider first. The dispatcher can trigger the SAM algorithm and, in this case, would get the proposal to replace the deadheading trip. In this use case, we would like to implement a mechanism where the system recognizes such a solution exists immediately when the task becomes unplanned and when the solution is straightforward enough (based on a given ruleset) to apply the solution without the intervention of a dispatcher.

Like the situation before, we would like to implement functionality where SAM proactively signals to the dispatcher when a solution for an unplanned task exists without first acting from the dispatcher. In the current way of working, good solutions did exist when the task became unplanned, but not anymore, as the dispatcher decided to prioritize the unplanned task.

SAM can solve a single unplanned task. However, in the case of a more significant disruption, multiple unplanned tasks occur on the same part of the network. We aim to implement logic that signals dependency between unplanned tasks and, when this is the case, decides not to run SAM automatically but rather advises the dispatcher to run the JIT solver.

5.3.2.2. Actors

- RU-Crew dispatchers

5.3.2.3. Pre-Conditions, Inputs

Pre-condition: there are one or more uncovered tasks.
Input: Real-time crew schedules, and real-time traffic control data.

5.3.2.4. Post-Conditions, Output

Automatic proposal to solve uncovered tasks.

5.3.2.5. Sequence

1. The crew dispatcher monitors conflicts and decides that these conflicts are solved fully automatically.
2. The algorithm automatically solves all conflicts.

5.3.2.6. Exchanged Data Instances

The data consists of a crew schedule in real time. This means the data contains an up-to-date timetable and a detailed schedule of tasks each crew member should perform. This means every available crew member has a duty that contains its current live location in the network and a planned set of tasks the crew member is set to perform. A task is an object that reflects a piece of work, for example driving from station A to station B departing at time x, and arriving at time y. Also, lunch breaks and other local tasks are given with the start and end times. Furthermore, the start- and end-time of the duty are given in the data.

5.3.2.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-25_R1	Non-Functional	Timeliness	The system should have access to accurate and complete real-time data regarding crew and timetable.	3
UC-FP1-WP10-25_R2	Functional	Usability	The system should propose and apply reasonable solutions that are recognizable for dispatchers.	5
UC-FP1-WP10-25_R3	Functional	Usability	The system should consider all labour rules that are in place, without causing additional conflicts	5
UC-FP1-WP10-25_R4	Functional	Usability	The user should be able to switch on/off the automatic mode.	3

Table 8 - Requirement table for UC-FP1-WP10-25

5.4. STS Uses Cases

5.4.1. UC-FP1-WP10-19 - Critical alarm management

5.4.1.1. Description

Within its life cycle, the various devices and systems deployed along a railway infrastructure may undergo a failure, which can be critical or not. The criticality of a failure depends on its impact on the safety of the overall infrastructure and the possible harm in terms of human lives and

economic consequences. Various risk assessment and management procedures exist within the current academic literature and industrial practice, but the one to be considered in this use case should be the common safety method (CSM) for risk evaluation and assessment ("the CSM REA") established by Commission Implementing Regulation 402/2013. It was designed to set out procedures and methods for carrying out risk evaluation and risk control whenever a change in operating conditions to the rail system is being made.
When a critical failure occurs, it is needed to promptly deal with it by performing various possible actions: rerouting trains, bringing the infrastructure to a safe state, or triggering an urgent maintenance action. Now, per each alarm case, well-established procedures define a set of actions to be executed to remedy the triggering situation. The operator can decide whether to execute this set and which action in this set can be executed. However, human errors are around the corner, and an automatic approach to support an operator is demanding. According to art. 22 of GDPR, automatic decisions that impact safety and human rights must be avoided, so the intention of the system is not to substitute a human operator but to support him/her by presenting a set of possible countermeasures. Still, the final decision is up to the operator. Therefore, the system supports the operator, reducing the effort and stress required to manage critical events by providing different types of support through the HMI. The layout proposal of the HMI is designed so that it can easily identify the critical states in various areas located on the dashboard and to support the operator in managing them according to the methods defined subsequently. The side pop-up windows follow a process/protocol (a succession of actions and commands) that aims at the normal work procedure or at solving any problems. Specifically, the various alarms codify a situation of failure and criticality, which are stored within the database of the DSS with possible to-do actions associated with them.

5.4.1.1.1. Actors

There is a set of actors that may potentially provide the alarm, such as an automatic monitoring system, or even a person along the infrastructure. The OCC operator and the train controller, Maintenance operator, Infrastructure manager, and others may see the alarm on their HMI and even a set of suggested countermeasures.

5.4.1.1.2. Pre-Conditions, Inputs

A failure occurs at a given device and system of the infrastructure. This can be automatically detected by sensors deployed within the infrastructure or by a human who has checked certain on-field measurements. The system receives an alert about the happened event as an input.

5.4.1.1.3. Post-Conditions, Output

If the event is considered critical, a sequence of actions is presented to the operator, who can choose to perform it.

5.4.1.1.4. Sequence

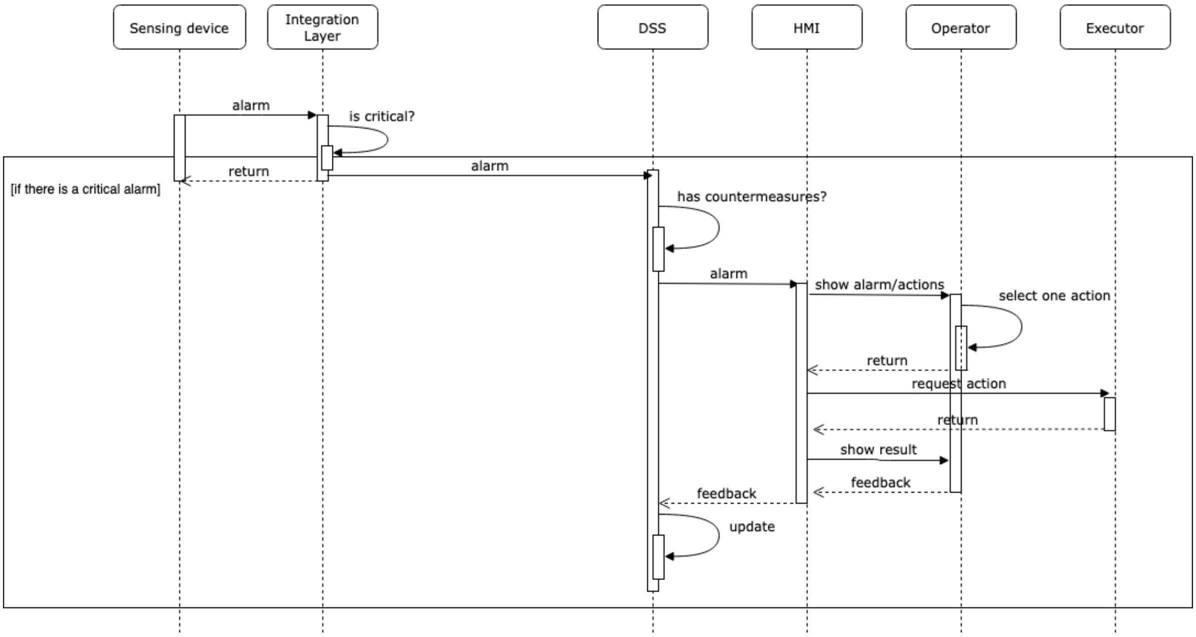

Figure 4 - Sequence diagram for the Use Case 12 - Critical alarm management

1. A failure happens at a device. It can be automatically detected by a sensor deployed at the device or by a human inspection. In both cases, an alarm is created.
2. The integration layer conveys the alarm to the HMI of the alarm management system.
3. The alarm is passed to the DSS, which checks if the alarm is critical and has a corresponding list of suitable actions to be performed, and it is passed to the HMI.
4. The system, through the HMI, provides support to the operator by:
   - Notifying the operator that the alarm occurred.
   - Showing the list of open procedures, including the one regarding the alarm that occurred.
   - Showing all the steps that have already been performed and the ones yet to be implemented for each procedure: a step can be an operation to be executed, a request for information, or a decision to be taken.
   - Each task, when implemented, affects the next proposed steps.
   - The list of steps is automatically updated.
   - When applicable, provide detailed and real-time information coming from various railway sub-systems for each step of the procedure.
   - The completion of each operation must be presented to the operator to ease the visualization of the overall process.
5. The operator may choose to execute the task from DSS.

The outcome of the action is evaluated by the DSS, thus presenting the next task to do. If the alarm is not critical, then the DSS does not manage it, but the alarm details is simply displayed at the HMI for operator convenience.
If the critical alarm does not have a procedure associated with it, DSS, when a suitable amount of user actions has been collected, can leverage ML techniques and create a procedure based on

actions performed by operators when solving alarms of the same type: in that case, HMI presents the procedure to the operator, clearly stating it is just a suggested procedure based on users' past experience. This is an advanced feature for a DSS-based management system; however, in the planned demonstrator it will not be realised, mostly because all the possible critical alarms are known, documented, and widely investigated. Such learning system may be of interest, despite implying increasing security issues in term of trustworthiness of the learning behaviour.

5.4.1.2. Exchanged Data Instances

The system receives as input an alarm, with the description of the failed element, a set of monitoring data to specify what failed and how. In output, we have a sequence of commands, and the entities responsible for performing such tasks.

5.4.1.3. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-19_R1	Functional	Usability	The system needs to be able to understand a received message containing an alarm or relative information. Moreover, per each alarm, its criticality needs to be properly determined.	5
UC-FP1-WP10-19_R2	Functional	Usability	Upon the reception of a critical alarm from IL, the system should visually present to the user all the relevant information, to identify the occurred disruption along with output coming from DSS and list all the communication means to help OCC operator to restore normal services quickly and safely.	5
UC-FP1-WP10-19_R3	Functional	Usability	In case of multiple alarms, the system should support the user to determine the most priority one and rank all alarms based on their severity.	3
UC-FP1-WP10-19_R4	Functional	Usability	In case of a disruption, the system should support the user in the identification of the root cause in an accurate manner.	4
UC-FP1-	Functional	Usability	The system needs to be user	3

WP10-19_R5			friendly and interact in a proper manner with the user.	
UC-FP1-WP10-19_R6	Functional	Usability	The system should be easy to use and train on novel alarm cases, even by a user without strong competences.	3
UC-FP1-WP10-19_R7	Functional	Usability	In case of an alarm not associated to a procedure, the system could provide a set of actions based on past training and interactions, clearly stating that the procedure has not been associated in configuration phase.	3
UC-FP1-WP10-19_R8	Functional	Extensibility	The system should be interoperable with any possible element in the infrastructure that may raise an alarm.	3
UC-FP1-WP10-19_R9	Non-Functional	Timeliness	From the time that the system receives an alarm, to the presentation to the user of possible actions/alarm information, there should be a reasonable time being passed to cope with real-time requirements.	5
UC-FP1-WP10-19_R10	Non-Functional	Scalability	The system should be always responsive for incoming alarms/requests, despite the workload being overwhelming.	5
UC-FP1-WP10-19_R11	Non-Functional	Security	Only registered and authorised entities can send alarm to the system, and the system should be able to cope with impersonating attempts.	3
UC-FP1-WP10-19_R12	Non-Functional	Security	Users need to be properly authenticated and authorised.	5
UC-FP1-WP10-19_R13	Non-Functional	Adaptability	DSS configurators must be able to insert new resolutions for new alarms and modify the existing ones with ease.	3
UC-FP1-WP10-19_R14	Non-Functional	Security	The system should always keep trace of the received alarms, the decided actions and the	5

			identification of the user who took care of the alarm and decided for its resolution.	

Table 9 - Requirement table for UC-FP1-WP10-19

5.4.2. UC-FP1-WP10-20 - Short-term management of a possible failure

5.4.2.1. Description

Railway infrastructure is made of various entities that may fail. For this reason, a series of sensors are deployed to monitor these devices by measuring their correct behavior and their structural features. Some of these measures can predict the occurrence of a failure before it happens, with a given probability. The integration layer conveys these measures to a DSS along with the possible scheduling of trains within the given portion of the railway infrastructure. The DSS receives an event with a high probability of failure when it is greater than or equal to a defined threshold (e.g., 90%) so it can notify the operator that it is needed to schedule a maintenance action. The system must estimate when and how the most preferable time to intervene is, if and how the traffic needs to be handled by rerouting trains, and what possible actions need to be taken. All these actions need to be presented to the operator through the HMI to actuate the best resolution.

5.4.2.1.1. Actors

A set of actors, such as an automatic monitoring system, may potentially provide the measurements to be used for failure prediction. The OCC operators are notified of the issue and the corresponding suggested countermeasures through the HMI.

5.4.2.1.2. Pre-Conditions, Inputs

A set of measurements are collected and can be used to predict failures that can occur at a given device and system of the infrastructure. This can be automatically collected from sensors deployed within the infrastructure or a human that has checked certain on-field measurements. The system receives these measurements as input.

5.4.2.1.3. Post-Conditions, Output

If the collected events are symptomatic of an upcoming failure, a sequence of actions is presented to the operator, who can choose to perform it and when.

5.4.2.1.4. Sequence

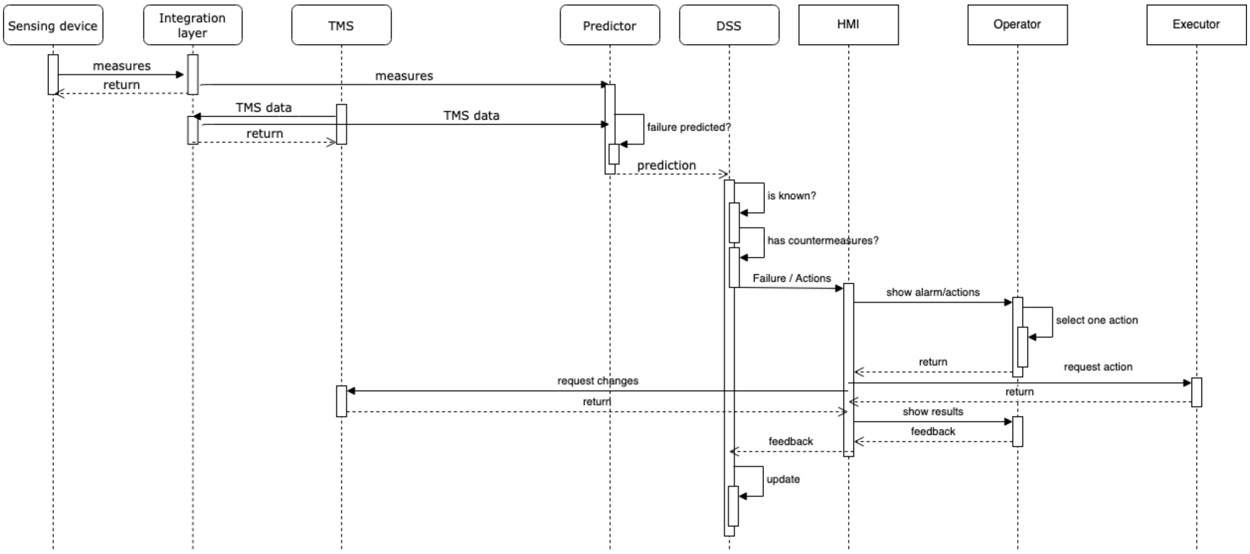

Figure 5 - Sequence diagram for the Use Case 13 - Short-term management of a possible failure

1. A set of measurements are collected by the system. These are automatically generated by a sensor deployed at the device or explicitly provided by a human inspection. In both cases, one or more measurement instances are created.
2. The measurement management system conveys the measurements to the integration layer. Additionally, TMS-related data are also collected and conveyed to know the train traffic state along the infrastructure and plans for future traffic.
3. The measurement management system determines if the measurements are symptomatic of an upcoming failure or not. This can be done by an embedded intelligence or even by interacting with another entity.
4. If the probability of determining a failure is over a given threshold, all the collected data is passed to the DSS, which checks if there is a sequence of operations associated with it. If it is, it will hold the sequence of actions to be performed, and it is passed to the HMI.
5. The system, through the HMI, provides support to the operator by Notifying the operator that a failure may occur with high probability.
   - Showing the list of the open procedures, including the one regarding the possible failure
   - Showing the most suitable date and time to perform the procedure, letting the operator choose.
   - When the chosen date and time occur:
     - Showing all the steps that have already been performed and the ones yet to be implemented for each procedure: a step can be an operation to be executed, a request for information, or a decision to be taken.
     - Each task, when implemented, affects the next proposed steps
     - The list of steps is automatically updated
     - when applicable, providing for each step of the procedure detailed and real-time information coming from various railway sub-systems such as the TMS

- The completion of each operation must be presented to the operator to ease the visualization of the overall process.

If the predicted failure has not a procedure associated to it, DSS, when a suitable amount of user actions has been collected, can leverage ML techniques and create a procedure based on actions performed by operators when solving alarms of the same type: in that case, HMI presents the procedure to the operator, clearly stating it is just a suggested procedure based on users' past experience.
As in the use case 12, this is an advanced feature, included to present a complete description of the use case, but it will not be considered in this project.

5.4.2.2. Exchanged Data Instances

The system receives as input a set of measurements and the TMS-related data, with the description of the failed element, a set of monitoring data to specify what may fail and how. In output, we have a sequence of commands, and the entities responsible to perform such commands.

5.4.2.3. Requirements

Requirement ID	**Functional/Non-Functional**	**Category**	**Description**	**Severity**
UC-FP1-WP10-20_R1	Functional	Usability	The system needs to be able to understand a received message containing a set of measurements or relative TMS data. Moreover, per each set of measures, its link to possible failures needs to be properly determined if exists.	5
UC-FP1-WP10-20_R2	Functional	Usability	Upon the reception of a set of measures from IL, the system should visually present to the user all the relevant information, to identify the monitored device along with output coming from DSS (both the failure detection and the remediation suggestion) and list all the communication means to help OCC operator to restore normal services quickly and safely.	5
UC-FP1-WP10-20_R3	Functional	Usability	In case of multiple failures being predicted, the system should support the user to determine	5

			the most priority one and rank all upcoming failures based on their severity.	
UC-FP1-WP10-20_R4	Functional	Usability	In case of a failure prediction, the system should support the user in the identification of the root cause in an accurate manner.	5
UC-FP1-WP10-20_R5	Functional	Usability	The system needs to be user friendly and interact in a proper manner with the user.	3
UC-FP1-WP10-20_R6	Functional	Usability	The system should be easy to use and train on novel unknown prediction cases, even by a user without strong competences.	3
UC-FP1-WP10-20_R7	Functional	Usability	In case of a failure prediction not associated to a procedure, the system could be able to provide an set of actions based on past training and interactions, clearly stating that the procedure has not been associated in configuration phase.	3
UC-FP1-WP10-20_R8	Functional	Extensibility	The system should be interoperable with any possible element in the infrastructure that may provide measures keen to make failure prediction, or even it should be simple to change and upgrade the used DSS solution.	3
UC-FP1-WP10-20_R9	Non-Functional	Timeliness	From the time that the system receives a set of measures, to the presentation to the user of possible actions/alarm information, there should be a reasonable time being passed to cope with real-time requirements.	5
UC-FP1-WP10-20_R10	Non-Functional	Scalability	The system should be always responsive for incoming measurements/requests, despite the workload being overwhelming.	5
UC-FP1-WP10-	Non-Functional	Security	Only registered and authorised entities can send measures to the	3

20_R11			system, and the system should be able to cope with impersonating attempts.	
UC-FP1-WP10-20_R12	Non-Functional	Security	Users need to be properly authenticated and authorised, and only those with the high level of authorization needs to be able to insert new resolutions for new failure predictions.	5
UC-FP1-WP10-20_R13	Non-Functional	Security	The system should always keep trace of the received measures, the decided actions and the identification of the user who took care of the alarm and decided for its resolution.	5

Table 10 - Requirement table for UC-FP1-WP10-20

5.4.3. UC-FP1-WP10-21 - Preventive Functional Assessment

5.4.3.1. Description

Within a railway infrastructure, some topological entities and devices are heavily used, and due to their usage, we have a continuous flow of monitoring data. As an example, the passage of trains allows us to get information on the correct behavior of rolling stock or tracks. When an entity or device is not used for a long time, it may have a lack of monitoring data able to assess its functional correctness. This is the case in which a Preventive Functional Assessment (PFA) is needed, and an on-field assessment is needed to check if the entity is in its valid and correct state. In fact, many railway companies must satisfy rules provided by safety regulations that, in several countries, define maintenance procedures and even the frequencies for preventive maintenance with the primary goal of providing a high level of safety. Such an operation needs to be properly planned by considering the actual and near-future traffic plan and the situation conditions within the infrastructure, achieving a rigorous control of service quality and cost-effectiveness of trains' circulation. Therefore, the system should alert the operator that a device needs to undergo a PFA intervention and a possible strategy plan.

5.4.3.2. Actors

Standard rules and maintenance obligations are modeled within a maintenance management system, which records the maintenance actions that occurred and determines when a PFA should be triggered.
The OCC operators are notified of the issue and its corresponding suggested countermeasures

through the HMI.

5.4.3.3. Pre-Conditions, Inputs

The Maintenance management system raises an alert that a device has not been subject to a maintenance action for too long and should be subject PFA.

5.4.3.4. Post-Conditions, Output

If PFA is needed, a set of possible actions is presented to the operator, who can pick the one that best fits his/her judgment and perform it.

5.4.3.5. Sequence

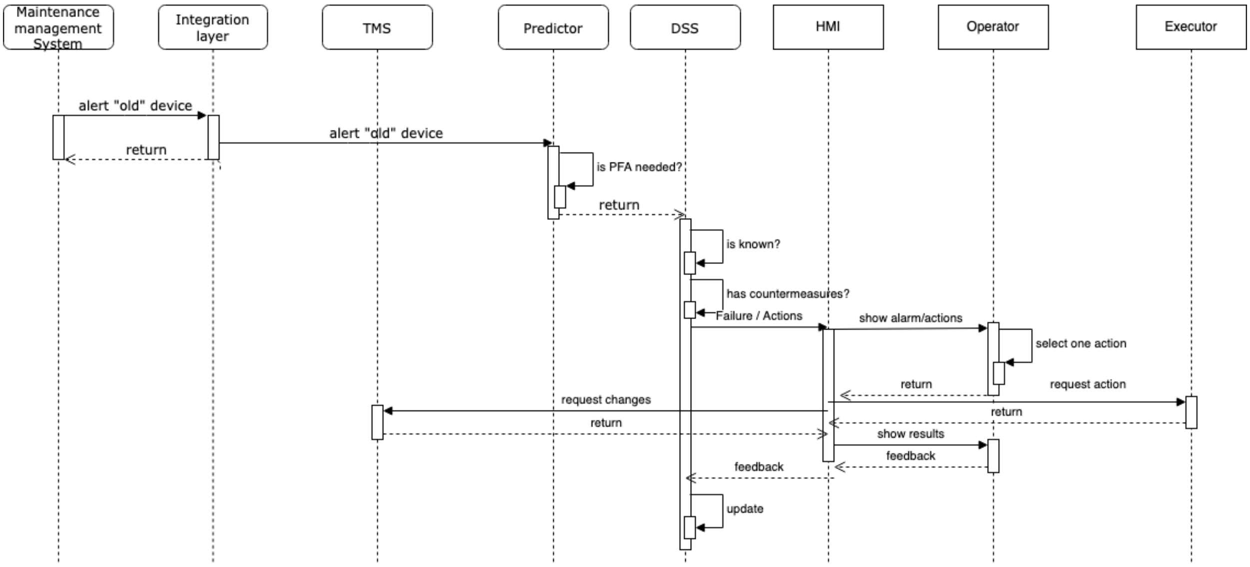

Figure 6 - Sequence diagram for the Use Case 14 - Preventive Functional Assessment

1. Throughout the integration layer, the Maintenance management system sends an alert related to a device that potentially has not been checked or used for a long period. This alert may be automatically generated by a proper ICT system modeling the maintenance standards or procedures or explicitly provided by a human.
2. The measurement management system conveys the alert to the integration layer. The DSS evaluates the alerts to determine whether they must be considered. Additionally, TMS-related data are also collected to determine the train traffic state along the infrastructure and plans for future traffic.
4. If the device is risky a PFA is needed, so the device details and TMS data to the DSS, which checks if the device and relative alert is known, i.e., internally modelled. If it is known, it will hold all the sequence of actions to be performed, and it is passed to the HMI.
5. The system, through the HMI, provides support to the operator by Notifying the operator

that a PFA is needed.

- Showing the list of the open procedures, including the one regarding the PFA
- Showing the most suitable date and time to perform the procedure, letting the operator choose.
- When the chosen date and time occur:
  - Showing for each procedure all the steps that have already been performed and the one yet to be implemented: a step can be an operation to be executed, a request for information, a decision to be taken.
  - Each task, when implemented, affects the next proposed steps
  - The list of steps is automatically updated
  - when applicable, providing for each step of the procedure detailed and real-time information coming from various railway sub-systems such as the TMS

- The completion of each operation must be presented to the operator to ease the visualization of the overall process.

If an alert related to a device does not have a procedure associated with it, DSS, when a suitable amount of user actions has been collected, can leverage ML techniques and create a procedure based on actions performed by operators when solving alarms of the same type: in that case, HMI presents the procedure to the operator, clearly stating it is just a suggested procedure based on users' past experience.
As in the use case12, this is an advanced feature, included to present a complete description of the use case, but it will not be considered in this project.

5.4.3.6. Exchanged Data Instances

The system receives an alert from the maintenance management system and the TMS-related data as input, describing the element of interest. In the output, we have a sequence of commands and the entities responsible for performing such commands.

5.4.3.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-21_R1	Functional	Usability	The system needs to be able to understand a received message containing a set of measurements or relative TMS data. Moreover, per each received alert, its link to possible harm and issues needs to be properly determined if exists. This is needed to determine if PFA is needed.	5
UC-FP1-WP10-21_R2	Functional	Usability	Upon the reception of an alert from IL, the system should	5

			visually present to the user all the relevant information, to identify the monitored device along with output coming from DSS (both the PFA decision and the remediation suggestion) and list all the communication means to help OCC operator to restore normal services quickly and safely.	
UC-FP1-WP10-21_R3	Functional	Usability	In case of multiple alerts being predicted, the system should support the user to determine the most priority one and rank all based on their severity.	5
UC-FP1-WP10-21_R4	Functional	Usability	In case of a PFA action being necessary, the system should support the user in the identification of the device/entity of interest in an accurate manner.	5
UC-FP1-WP10-21_R5	Functional	Usability	The system needs to be user friendly and interact in a proper manner with the user.	3
UC-FP1-WP10-21_R6	Functional	Usability	The system should be easy to use and train on novel unknown alerts, even by a user without strong competences.	3
UC-FP1-WP10-21_R7	Functional	Usability	In case of an alert not associated to a procedure, the system could be able to provide a set of actions based on past training and interactions, clearly stating that the procedure has not been associated in configuration phase.	3
UC-FP1-WP10-21_R8	Functional	Extensibility	The system should be interoperable with any possible element in the infrastructure that may provide measures keen to make failure prediction, or even it should be simple to change and upgrade the used DSS solution.	3
UC-FP1-	Non-Functional	Timeliness	From the time that the system	5

WP10-21_R9			receives an alert, to the presentation to the user of possible actions/alarm information, there should be a reasonable time being passed to cope with real-time requirements.	
UC-FP1-WP10-21_R10	Non-Functional	Scalability	The system should be always responsive for incoming alerts, despite the workload being overwhelming.	5
UC-FP1-WP10-21_R11	Non-Functional	Security	Only registered and authorised entities can send alerts to the system, and the system should be able to cope with impersonating attempts.	3
UC-FP1-WP10-21_R12	Non-Functional	Security	Users need to be properly authenticated and authorised, and only those with the high level of authorization needs to be able to insert new resolutions for new alerts.	5
UC-FP1-WP10-21_R13	Non-Functional	Security	The system should always keep trace of the received alerts, the decided actions and the identification of the user who took care of the alarm and decided for its resolution.	5

Table 11 - Requirement table for UC-FP1-WP10-21

5.5. TRV/VTI Uses Cases

5.5.1. UC-FP1-WP10-26 – Trespassing

The use case is intended to describe a critical event that occurs frequently and requires an immediate and strong response from the dispatcher/TMS operator.

5.5.1.1. Description

This use case consists of the detection of one or more unauthorized persons entering the track area. Today, most often, it is a train driver who detects the person/-s and contacts the dispatcher/TMS operator using voice communication channels. The dispatcher/TMS operator then stops the traffic or gives directives of restricted speed until the police or other rescue services have taken care of the person/-s, or the dispatcher/TMS operator, in another way, can confirm that the track is clear again. Trespassing causes a lot of delays and is today the main cause of injuries and deaths in the railway system.

5.5.1.2. Actors

- The dispatchers/TMS operators are the ones who decide to restrict traffic in some way.
- The train driver most often detects unauthorized persons in the track area and calls the dispatcher/TMS operator.
- The emergency/rescue services, which have the task to take care of the unauthorized persons in the track area.

5.5.1.3. Pre-Conditions, Inputs

A train driver has identified unauthorized people close to the track and contacts (gives input to) the dispatcher/TMS operator by voice communication channels about the potentially dangerous situation. For safety reasons and according to safety rules, the track needs to be blocked by the dispatcher/TMS operator. There is a well-functioned TMS allowing the dispatcher/TMS operator (actors defined) to fulfil the management task described below.

5.5.1.4. Post-Conditions, Output

The dispatcher/TMS operator is informed that the trespassing problem is solved and uses a proper command provided to TMS for the re-plan of the traffic accordingly.

5.5.1.5. Sequence

1. The dispatcher/TMS operator is informed via voice communication channels (interface) that a trespassing has occurred and the operator therefore block the identified area by a proper command in the TMS interface so the blocking becomes visually for the train drivers via the signaling system and ATP used (interface, trackside and/or onboard). The dispatcher/TMS operator also uses voice communication (interface) to inform all the directly affected trains (i.e., train drivers) about the restrictions given by the command in the TMS.
2. The affected area is protected from train traffic by the dispatcher/TMS operator who 1) uses a proper command in the TMS (interface), and 2) uses voice communication channels (interface).
3. The emergency/rescue services are contacted by the dispatcher/TMS operator using voice communication channels (interface) and is directed send to the area of interest.
4. The DSS lists suitable actions to be performed which is shown to the dispatcher/TMS operator (in the TMS (interface) to support them in taking actions.

5. The emergency/rescue services search the area and contact the dispatcher/TMS operator using voice communication channels (interface) when the track area is clear from intruders.
6. When the track area is confirmed clear by the emergency/rescue team, the dispatcher/TMS operator unblocks the area in question by using the proper command in the TMS (interface) and the traffic re-planning continues accordingly.

5.5.1.6. Exchanged Data Instances

Information	From	To	Comments/Data
Trespassing is detected and the position of the unauthorized persons is communicated by voice channel.	Train driver	Dispatcher/TMS operator	Position (of the trespassing).
Proper command for the protected area.	Dispatcher/TMS operator	TMS	Command
List of suitable actions to handle the disturbance occurred by the trespassing.	DSS	Dispatcher/TMS operator	Options of actions
Re-write train plan by proper command.	TMS	Dispatcher/TMS operator	Dispatcher/TMS operator approves train plan./Command
Search request	Dispatcher/TMS operator	Emergency/rescue services	Request
Track area clear	Emergency/rescue services	Dispatcher/TMS operator	Clearence message
Traffic restart	Dispatcher/TMS operator	TMS	Command

Table 12 - Exchanged data in UC-FP1-WP10-26

5.5.1.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-26_R1	Functional	Usability	The system shall provide integrated support in the	4

			managing of traffic after a severe perturbation.	
UC-FP1-WP10-26_R2	Functional	Usability	The system helps to coordinate and to supervise multiple operators involved in the resolution of disruptive issues, to provide optimal solutions in complex scenarios.	4
UC-FP1-WP10-26_R3	Functional	Usability	To support the coordination among different operators involved in the management of critical tasks, the system shall facilitate communication.	5
UC-FP1-WP10-26_R4	Functional	Usability	The system shall provide information about which operator is managing a task.	3
UC-FP1-WP10-26_R5	Non-Functional	Timeliness	The system shall provide real-time information about the status of the railway system.	5
UC-FP1-WP10-26_R6	Functional	Usability	The system shall improve digitalization of communications between parties involved (users).	4
UC-FP1-WP10-26_R7	Functional	Usability	The system shall provide a channel for voice-based communication between actors involved.	5
UC-FP1-WP10-26_R8	Functional	Accessibility	The system shall always provide a way for the actors to communicate critical information.	5
UC-FP1-WP10-26_R9	Functional	Usability	The system shall be based on the principles of HMI developed in WP13.3	5

Table 13 - Requirement table for UC-FP1-WP10-26

5.5.2. UC-FP1-WP10-28 – Infrastructure Problems Detected by Railway Staff

The use case is intended to describe an event that can be critical under certain circumstances and, if so, requires an immediate and strong response from the dispatcher/TMS operator.

5.5.2.1. Description

A train driver has identified infrastructure problems and contacts the dispatcher/TMS operator by voice. The dispatcher/TMS operator understands that actions are needed based on the information given by the train driver. Based on the information given by the driver, the dispatcher/TMS operator must decide if the traffic can continue and under which conditions. In this situation, the dispatcher/TMS operator needs the railway maintenance staff's support to determine the severe problem and which subsequent actions are appropriate. The dispatcher/TMS operator, therefore, contacts the maintenance coordinator by voice communication channels, who sends personnel into the field. The maintenance staff examines that infrastructure and sends (by voice communication channels) information to the dispatcher/TMS operator that has different alternatives for the problem. In all cases, the decision is communicated to the TMS using proper commands.

5.5.2.2. Actors

- The dispatchers/TMS operators
- The train drivers
- Maintenance personnel

5.5.2.3. Pre-Conditions, Inputs

- The train driver identifies a possible infrastructure problem and contacts (gives input to) the dispatcher/TMS operator through the voice channels interface.
- A well-functioning TMS allows the actors defined to fulfill the management task.

5.5.2.4. Post-Conditions, Output

- The maintenance personnel inform the dispatcher/TMS operator that the problem is solved.
- The dispatcher/TMS operator uses a proper command provided to TMS for the re-plan of the traffic accordingly

5.5.2.5. Sequence

1. A train driver detects an infrastructure problem.
2. The dispatcher/TMS operator is informed that an infrastructure problem exists and therefore blocks the identified area by a proper command in the TMS interface, so the blocking

becomes visually for the train drivers via the signalling system and ATP used (interface, trackside and/or onboard). The dispatcher/TMS operator also uses voice communication to inform all the directly affected trains (i.e., train drivers) about the restrictions given by the command in the TMS.

3. The affected area is protected from train traffic by the dispatcher/TMS operator i) using a proper command in the TMS interface and ii) using the voice communication channels interface.
4. The maintenance personnel are contacted by the dispatcher/TMS operator using voice communication channels interface and are directed to the area of interest.
5. DSS gives proposals on possible traffic management in the TMS interface.
6. The maintenance personnel contact the dispatcher/TMS operator using a voice communication channels interface when the problem is examined and inform the dispatcher/TMS operator of the status of the problem.
7. The dispatcher/TMS operator decides on the level of access to the area based on the information given by the maintenance personnel executing appropriate commands in the TMS interface.
8. DSS updates proposals in the TMS interface based on the level of access.
9. The traffic is re-planned by the dispatcher/TMS operator and continues accordingly.

5.5.2.6. Exchanged Data Instances

Information	**From**	**To**	**Comments**
Position of a possible infrastructure problem is communicated by voice channels.	Train driver	Dispatcher/TMS operator	Position (of the problem identified)
Protect area by proper command.	Dispatcher/TMS operator	TMS	Command
List of suitable actions to handle the disturbance occurred by the trespassing.	DSS	Dispatcher/TMS operator	Options of actions
Re-write train plan by proper command.	Dispatcher/TMS operator	TMS	Command
The position of the eventual infrastructure problem.	Dispatcher/TMS operator	Maintenance personnel	Maintenance personnel examine the problem in the field. /Direction
Infrastructure problem status is communicated to	Maintenance personnel	Dispatcher/TMS operator	Status

the dispatcher/TMS operator by voice communication channels.			
New traffic plan approved by proper command.	Dispatcher/TMS operator	TMS	Command

Table 14 - Exchanged data in UC-FP1-WP10-28

5.5.2.7. Requirements

Requirement ID	Functional/Non-Functional	Category	Description	Severity
UC-FP1-WP10-28_R1	Functional	Usability	The system shall provide integrated support in the managing of traffic after a severe perturbation.	4
UC-FP1-WP10-28_R2	Functional	Usability	The system helps to coordinate and to supervise multiple operators involved in the resolution of disruptive issues, in order to provide optimal solutions in complex scenarios.	4
UC-FP1-WP10-28_R3	Functional	Usability	In order to support the coordination among different operators involved in the management of critical tasks, the system shall facilitate communication.	5
UC-FP1-WP10-28_R4	Functional	Usability	The system shall provide information about which operator is managing a task.	3
UC-FP1-WP10-28_R5	Non-Functional	Timeliness	The system shall provide real-time information about the status of the railway system.	5
UC-FP1-WP10-28_R6	Functional	Usability	The system shall improve digitalization of communications between	4

			parties involved (users).	
UC-FP1-WP10-28_R7	Functional	Usability	It shall improve interaction of the TMS with the Maintenance System.	4
UC-FP1-WP10-28_R8	Functional	Usability	The system shall provide a channel for voice-based communication between actors involved	5
UC-FP1-WP10-28_R9	Functional	Usability	The system shall always provide a way for the actors to communicate critical information	5
UC-FP1-WP10-28_R10	Functional	Usability	The system shall be based on the principles of HMI developed in WP 13.3	5

Table 15 - Requirement table for UC-FP1-WP10-28

6. Conclusions

This document presented the analysis of the main use cases for disruption management from the participants of Task 13.1. Each analysis contains a description of the use case, actors involved in the use case, their interactions, and pre-conditions and post-conditions for the use case implementation. The data instances exchanged during the use case execution and the requirements the planned demonstrators within WP14 should satisfy are also covered. Specifically, we have detailed the description of 12 use cases by highlighting 97 requirements classified among functional and non-functional ones and assigning each of them a severity level. Such a level indicates how mandatory the requirement to be included in the demonstrator for D14.1 is. These requirements represent a more detailed elicitation concerning D10.1 and will be considered for the design and implementation done in the next steps of WP13 and reported in D13.2.

7. References

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[D2.3] Deliverable D2.3 - Demonstration of enhanced and integrated line- and yard planning and possibilities for implementation

[D10.1] Deliverable 10.1 - Mapping against scope, specification of technical enablers, high-level use cases, high-level requirements, high level design for demonstrators in WPs 11-18

[D10.2] Deliverable 10.2 - Definition of Data elements for demonstrators in WPs 11-18

[D13.2] Deliverable 13.2 - Report on the design of HMI and development of DSS for disruption management

[D14.1] Deliverable 14.1 - Definition of Data elements for demonstrators in WPs 11-18

[EU-RAIL MAWP] Europe’s Rail Joint Undertaking Multi-Annual Work Programme, Version 2.0, 1 March 2022 https://rail-research.europa.eu/wp-content/uploads/2022/03/EURAIL_MAWP_final.pdf

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