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UNIVERSIDAD DE SEVILLA
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A2.D2.1 Framework for the design and use of digital assets: state of the art. Milestone 1

**“Asset MAnagement in the new Digital Twins
environment” (AMADIT)**

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REFERENCIA: PID2022-137748OB-C32	
TITULO: GESTION DE ACTIVOS EN EL NUEVO ENTORNO DE LOS GEMELOS DIGITALES (AMADIT)	
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1. INTRODUCTION

In the current technological development environment of maintenance management, not applying digitisation can leave organisations behind. The application of this technology should be analysed from a global business perspective, looking at the advantages and disadvantages. The strengths of maintenance digitisation can be summarised as follows:

- Improved operational efficiency by enabling more efficient management of resources and optimising costs and response times in decision-making.
- Access to advanced technologies, such as IoT and AI, provides tools for data-driven decision-making, improving early failure detection and predictive maintenance.
- Improved sustainability, as digital tools help meet their sustainability goals.

These strengths foster several opportunities for organisations to position maintenance management, such as improving the implementation of predictive maintenance techniques, improving operational agility by responding quickly to disruptions, and enabling more complex simulations to increase scalability.

However, organisations are not ready to adopt these technologies due to a lack of digital infrastructure, workforce resistance to change, and heavy upfront investment in infrastructure and training. Using these technologies exposes organisations to cybersecurity risks, potentially opening up new vulnerabilities that could threaten the integrity of their data and operations.

Digitising maintenance processes provides organisations with improvements in several areas:

- Efficiency gains by reducing the time needed to identify and address problems due to automated diagnostics, intelligent scheduling or remote monitoring.
- Cost savings by optimising unplanned downtime through predictive modelling, reducing preventative tasks and unneeded repairs, and extending the life of assets.
- Increased predictive capabilities by enabling prediction of when and where failures are likely to occur. This capability is achieved through real-time data from IoT sensors, AI algorithms and machine learning models.
- Improved asset reliability: Real-time data allows for more accurate decisions, reducing the likelihood of unexpected failures and increasing system reliability.
- - Data-driven decision-making allows for optimising maintenance activities and aligning your strategy with organisational goals.
- - Digital processes enable more sustainable maintenance practices by reducing waste, improving energy efficiency and optimising resources.

Some considerations have to be made regarding the concept of digitisation of assets and the framework for digitisation before tackling digitisation. Subsequently, the data structure for digital assets and the platform for placing data and models are discussed.

2. CONSIDERATIONS ON DIGITISATION

Concept of asset digitisation

In English literature, three terms describe digitisation: ‘digitisation’, ‘digitalisation’, and ‘digital transformation’. Each has its meaning and a particular translation into English.

‘Asset digitisation: This refers to creating a foundational data and information model for a physical asset in digital format. A digital twin (DG) is generated with the necessary level of detail. Digitisation is the basic conversion of something physical to digital.

‘Asset digitalisation’ goes beyond digitisation to encompass the improvement and transformation of processes, products, and services, starting with creating and continuously updating the DG. It seeks to improve the value and management of assets. Digitalisation focuses on how digital tools can transform or improve processes and how value is realised.

‘Digital Transformation’: A broad strategic approach that aligns with business transformation objectives, where you redefine your culture, operations, products and customer experience through digital technology. Digitalisation is part of digital transformation and helps shape business and societal

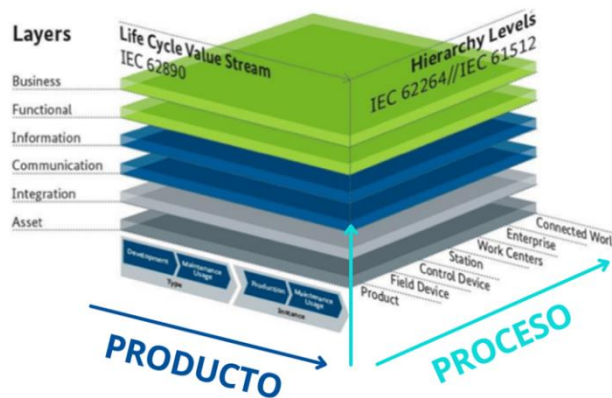
outcomes.

Framework and Standards for Digitalisation

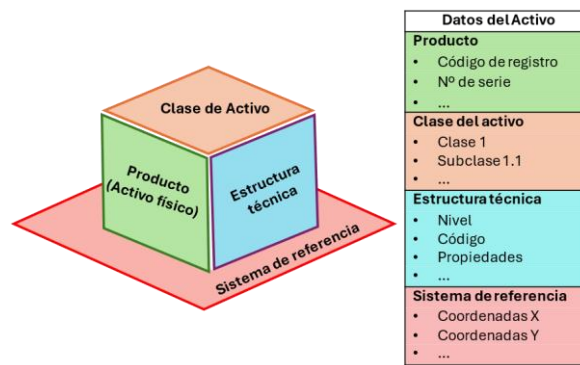
A framework must be created to design a DG. To define it, we have considered several Standards and two reference frameworks (RAMI 4.0 and IIRA) to address the integration of digital assets in the context of Industry 4.0 and IIoT.

ISO/IEC/IEEE 42010:2011, Systems and software engineering - Architecture Description. This Standard defines architecture as a system's fundamental structure, including its components' structure, their relationships and the principles and guidelines that govern its design and evolution over time. UNE-EN IEC 81346-1:2022, Industrial systems, installations, equipment, and industrial products. Structuring principles and reference designations. Part 1: Basic rules. The Standard provides principles for classifying and categorising objects within industrial systems, equipment and plants. It also provides a common language for identifying system components according to function, location and product type. It ensures consistency and operability between platforms and technologies, such as IoT, MDM and asset management systems. UNE-EN ISO 14224:2016, Petroleum, petrochemical and natural gas industries. This Standard addresses the collection and exchange of maintenance and equipment reliability data.

In addition to standards, two reference frameworks for asset digitisation have been developed. RAMI 4.0 is a reference architecture, essentially a ‘roadmap’ that structures Industry 4.0 technologies along three main axes, facilitating the understanding and planning of industrial digitisation: The first axis structures the hierarchy levels for digitisation, showing the levels in an industrial plant (from the product to the connections to the cloud). The second axis deals with the value stream of the product or system lifecycle. The third axis develops the functional layers, representing the technological architecture required for digitisation, asset, integration, communication, information, function, and business layers. One of the most essential layers in this model is the ‘Asset’ layer, which represents the physical assets.

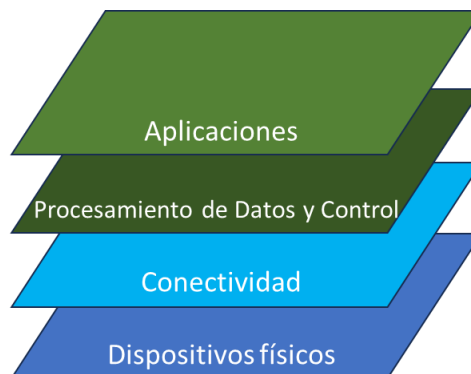


The Asset Administration Shell (AAS) is the digital representation of a physical asset within the Industry 4.0 ecosystem. The AAS acts as the DG of the physical asset, gathering all relevant information about it, such as technical data, operating characteristics, current status, capabilities and functionalities, and positioning. This representation allows the asset to be monitored, managed, and communicated within the interconnected industrial environment.



The IIRA is another key framework designed specifically for the IIoT to design and implement scalable, interoperable and secure solutions based on the modularity of construction. The IIRA is based on a four-layer model that organises and classifies the components of the IIoT system. The layers are:

- The physical Devices Layer includes the physical assets and connected devices in the industrial environment, such as sensors, actuators, machines, and robots.
- The connectivity Layer focuses on communication technologies for data transfer between physical devices and processing systems, such as Ethernet, Wi-Fi, 5G, or industrial networks.
- The Data Processing and Control Layer deals with real-time data processing and automated decision-making.
- The applications Layer contains the applications and systems for management-level decision-making, such as ERP or MES. It also includes data analytics, AI and other advanced tools.



3. DATA STRUCTURE FOR DIGITAL ASSETS

According to the proposed Standards and frameworks, it is recommended that a structure consisting of four types of data models be developed: Asset Definition Models (ADM), Asset Criticality Models (ACM), Asset Monitoring Models (AMM), and Intelligent Asset Maintenance Models (IAMM).

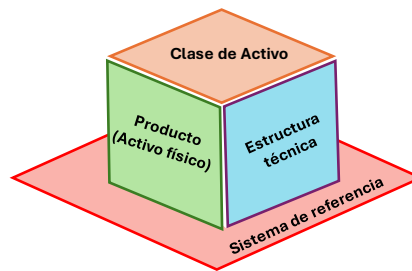
Asset Definition Models (ADM)

This model type serves as a framework for describing and managing asset data from different systems, applications or monitoring.

The proposed asset definition model includes four dimensions to ensure the recording, classification, location and reference of the asset in a way that supports digitisation and integration into management systems:

- Physical asset registration data. Its central element is the code that can be used as a unique identifier. It enables the tracking and management of the asset throughout its lifecycle. It also links the physical and digital worlds (empowers the development of DG). In addition, the model includes other product-specific data (protocols, commissioning, power, dimensions, ...).

- The data on the technical structure of the asset. This is data related to the technical structure (frequencies, special tools, ...). This concept is essential for composing larger systems. The technical structure of the asset is related to the location physically occupied.
- The asset class data describes the technology and technical specifications of the asset (it is not dependent on its functional location and technical structure). Classes allow the grouping of assets according to their shared characteristics (function, technology, etc.). They are used to define the catalogue of failure modes for each asset and the maintenance plans.
- Asset reference system data uses coordinates to geolocate assets. Geolocating is essential for managing mobile or distributed assets over large areas. Integrating this system with IoT platforms further enhances the ability to track and monitor assets in real time.



Asset Criticality Model (ACM).

This model provides the basis for decision-making. It is based on risk analysis and facilitates the allocation of resources, prioritising assets according to their criticality. This model makes it easier to focus efforts on those assets that have the most significant impact on the business (security, performance, availability, etc.).

MATRIZ DE CRITICIDAD											#	
Frecuencia Baja	0 VER	0 VER	107 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	2	107
Frecuencia Alta	10 VER	8 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	1,8	18
Frecuencia Media	47 VER	0 VER	7 VER	0 VER	89 VER	0 VER	21 VER	5 VER	0 VER	0 VER	1,2	174
Frecuencia Alta	3965 VER	583 VER	588 VER	135 VER	172 VER	37 VER	63 VER	49 VER	3 VER	7 VER	1	5603
Consecuencia 0	30	20	30	40	50	60	70	80	90	100		5942
#	4822	551	702	135	241	37	84	54	3	7	46	5942

This model must be large-scale applicable, consistent with the organisation's asset management strategy, and able to adapt to changes over time.

The ACM functions as a central component to which other asset management models are connected. These connections include preventive maintenance planning, real-time monitoring, and life-cycle cost analysis.

Asset Monitoring Model (AMM)

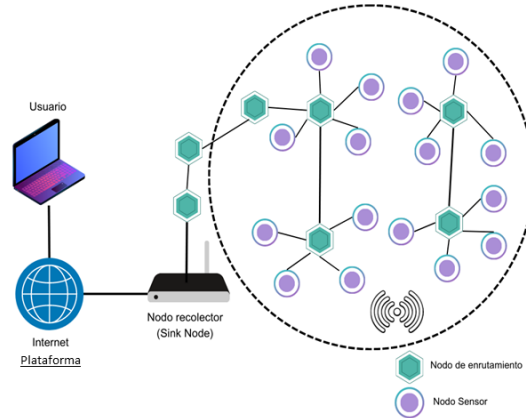
This model provides the necessary infrastructure for real-time monitoring and decision-making. Organisations can obtain continuous information about asset conditions using IoT networks and on-platform computing.

The collected data is processed using an extract, transform, and load (ETL/ELT) system, where signals are converted into meaningful and actionable information about the asset's condition and performance. This model requires the following features: the design of IoT networks and signal processing components, the design of the asset monitoring system, integration with other asset digitisation models, integration of hardware and software, and the definition of the centralised processing server.

IoT and Signal Processing Networks comprise three main components: sensors, nodes, and computing systems on the platform. Sensors are installed on the asset to measure physical parameters in real-time (temperature, vibration, strain, pressure, etc.). Nodes aggregate data from several sensors, ensuring efficient communication and data transfer. In some cases, nodes are

responsible for local data processing and transmitting information to the platform. Cloud computing systems store, analyse, and provide data.

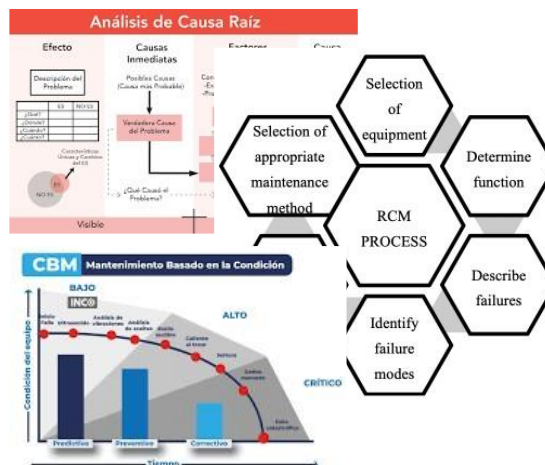
The asset monitoring system's design follows an IoT-based framework, which includes three layers: local data acquisition and processing, a data transport network to the platform, and a processing server (responsible for executing the ETL/ELT process). To ensure scalability, the system can adopt a microservices-based architecture. This approach allows the system to handle large-scale data from multiple assets. It ensures that each component, whether data collection, storage, or analysis, can be managed independently and scale as needed.



Integration with other real-time asset scanning models allows organisations to gain a holistic view of asset performance, health, and criticality. Integration also includes the hardware and software elements, involving local and platform-based systems, to process and analyse the data. Finally, the server is responsible for centralised data processing and management.

Intelligent Asset Maintenance Models

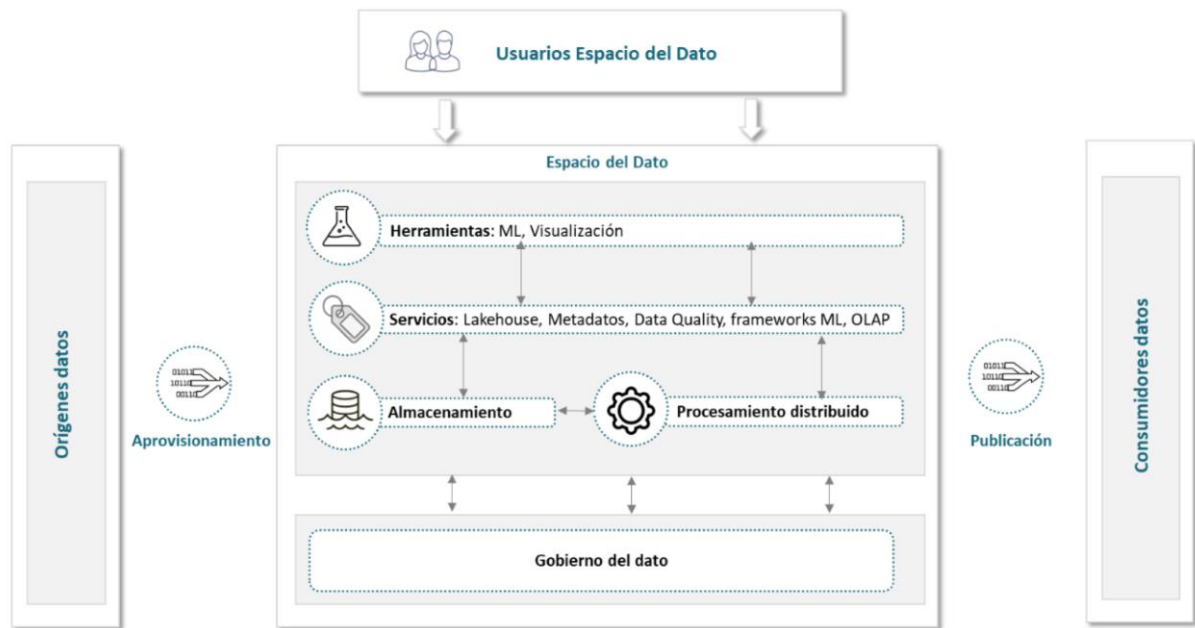
Intelligent Asset Maintenance Management Models (IAMM) represent the final layer in asset digitisation. After capturing, processing and structuring an asset's data (asset definition and monitoring models) and addressing its criticality (criticality model), the need arises to connect to decision-making and management tools. They integrate historical and real-time asset data to develop advanced processes that aid decision-making.



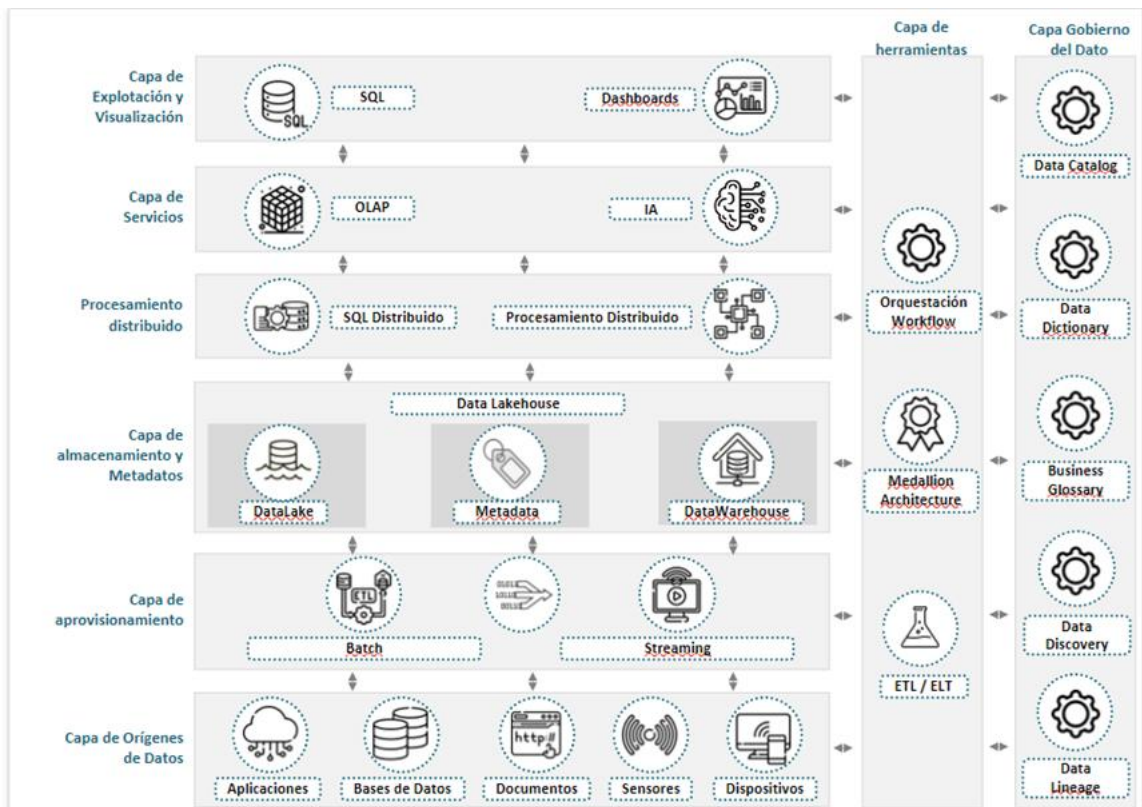
Intelligent asset management is based on integrating data models that enable the automatic execution of methodologies: Root Cause Failure Analysis (RCFA), Reliability-Centred Maintenance (RCM), or Preventive and Condition-Based Maintenance (PM & CBM). Integrating these data models ensures that decision-making processes are optimised and that simulation and predictive analytics tools are leveraged to generate actionable information.

4. LOCATION OF INFORMATION. PLATFORMS

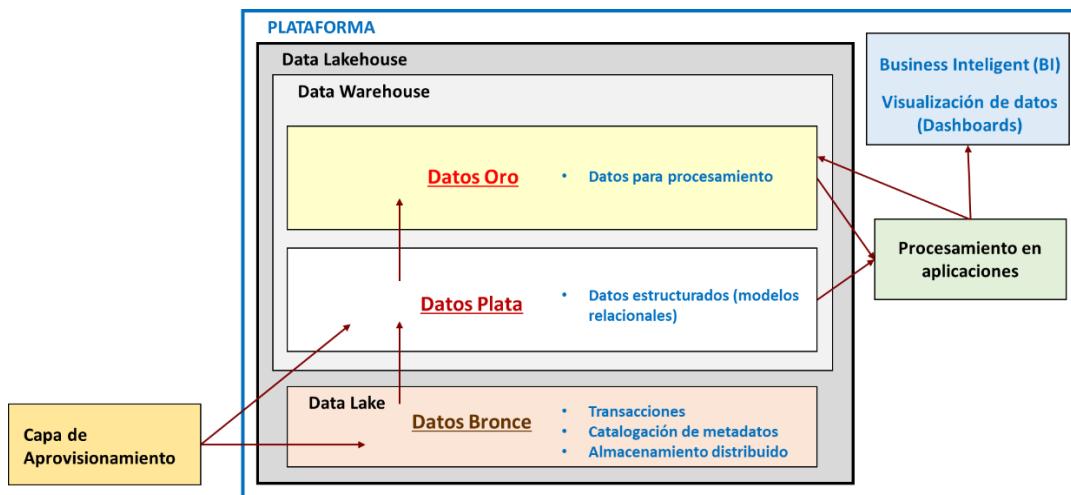
Platforms for hosting DG should present, enable, and store structured, semi-structured, and unstructured data; clean and catalogue data; provide the necessary tools for data analysis; and perform descriptive analysis, e.g., dashboards, simulations, and prescriptive or predictive analysis.



The conceptual model of the platform architecture contains at least nine layers: data source layer, provisioning layer, storage and metadata layer, processing layer, services layer, data exploitation, visualisation and publishing layer, consumption layer, data governance layer and tools layer. The data source layer is not, strictly speaking, an element of the architecture. Still, it is necessary as it represents the possible data sources (sensors, CMMS applications, cloud applications, databases, devices, websites, etc.). The provisioning layer connects the different data sources to perform the data extraction and hosting processes. The storage and metadata layer is accountable for hosting and organising all the data published on the platform (data space). It must allow for horizontal scaling and distributed storage. The processing layer executes all the processes of data cleansing, extraction, transformation, aggregation, Machine Learning model training, etc. The services layer must provide the platform with value-added functionalities, such as Advanced Analytics frameworks (machine learning, AI), access to the distributed storage layer as DB services, or multidimensional OLAP models that enable descriptive analytics. La capa de explotación, visualización y publicación de datos es responsable de realizar las conexiones necesarias para publicar estos datos de forma segura (Dashboard). The data exploitation, visualisation and publication layer is responsible for making the necessary connections to publish this data securely (Dashboard). The consumption layer is accountable for making the most of the storage and processing layers after executing the value-added functionalities to the platform. The data governance layer collects practices, policies and roles related to acquiring, managing and effectively using data. Data governance confirms the quality and security of an organisation's data, determining who can use what data and when. The tools layer is responsible for providing tools to end users that enable them to carry out their work conveniently, efficiently and reusable.

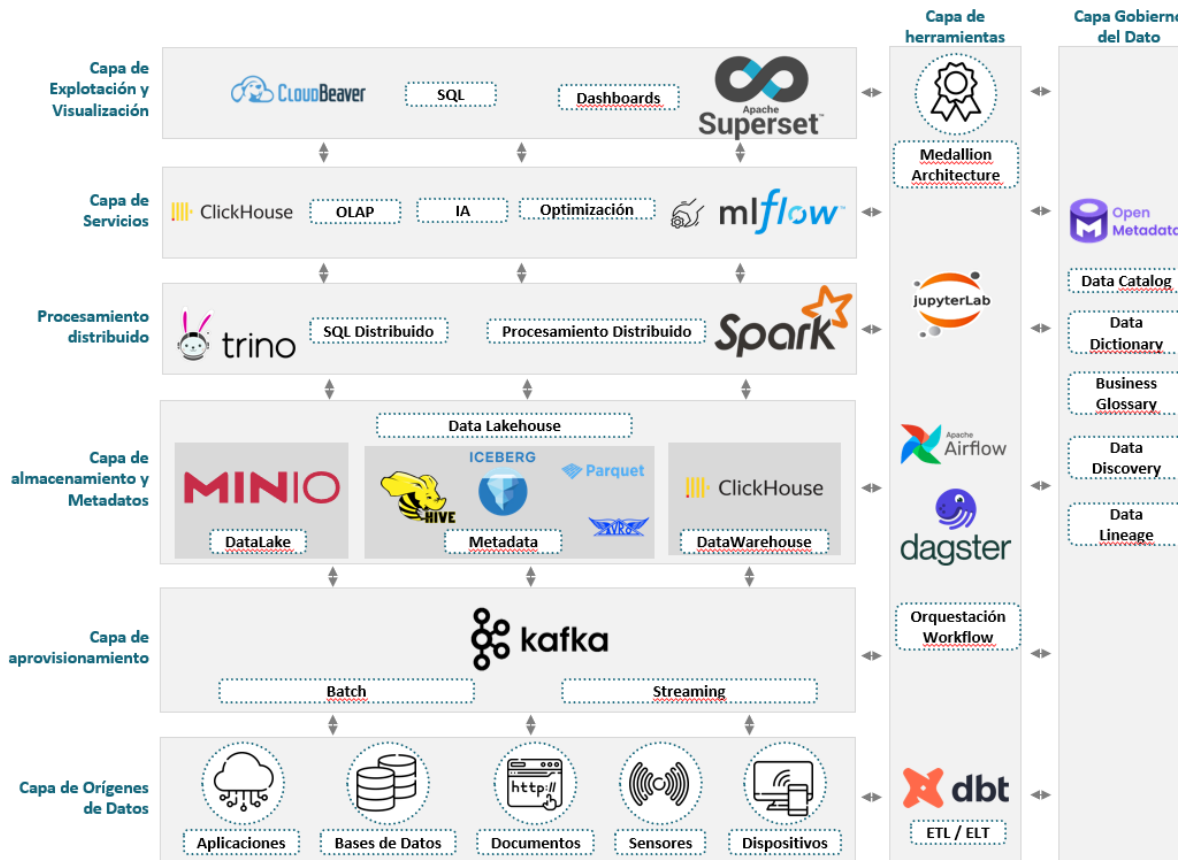


The architecture is intended to be robust, modern, modular, extensible, and scalable, consisting of solutions that meet the current and future requirements of the DGs. The provisioning layer integrates the Apache Kafka solution, enabling real-time data provisioning and message queue subscription. The storage layer consists of a Data Lakehouse composed of a Data Lake that stores raw data (bronze data) and a Data Warehouse that stores structured and/ or processing data (silver and gold data).



This layer requires processing and curating the data using MinIO, an object-based solution compatible with Amazon S3 and used for distributed storage in the Data Lake. It will also use Apache Hive Metastore to manage massive datasets and query and catalogue metadata. The distributed processing layer includes selected data and model transformation technologies, cleansing, aggregation and processing. It uses TRINIO as a query engine and Apache Spark as a framework for building distributed computing systems. The service layer solutions are ClickHouse, a columnar database and Mlflow to simplify the machine learning lifecycle. The exploitation and visualisation layer uses interface solutions such as Superset and database management solutions such as CloudBeaver. The data governance layer uses the OpenMetaData metadata warehouse. The tools

layer uses DBT for building and managing data pipelines, Dagster for orchestrating data flows, JupyterLab for creating and sharing web documents, and Apache Airflow for developing, scheduling and monitoring pipelines.

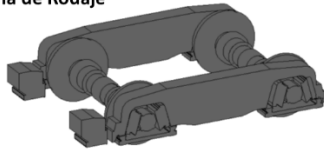


5. CASE STUDY

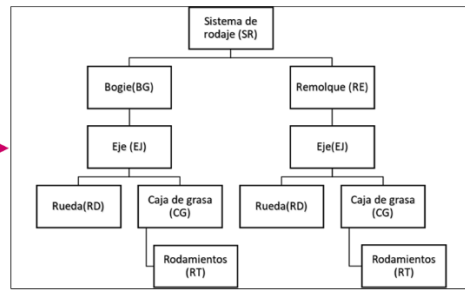
Following the structure of data models and their location in the platform exposed in sections III and IV, the DG has been designed for a confirmed case of maintenance management of a fleet of 54 rail track repair machines, the workshop, the workshop tools and the human resources authorised to carry out the maintenance tasks. The DG implementation has reached the TR4 level. The data models of the machines have been implemented for two types of machines (tamping machines and profiling machines): the data model of the workshop and its tools, human resources, and spare parts. The intelligent maintenance models have been implemented to optimise the default preventive, condition-based and workshop intervention planning. The process of obtaining the CAS (Certificate of Fitness for Service / similar to the MOT for vehicles) has also been digitalised. For this purpose, the functional structure of each machine had to be determined to relate each CAS task (more than 400) to the checked physical element. In addition, several failure modes have been digitised, and the relationships with machine elements, tools, spare parts and human resources have been established.

Several companies have been involved in the development, and the asset owner has designed the data models of the machines, the workshop, and the processes. Another developed the platform. A third was responsible for the extraction and transmission of the data. A fourth has scanned the workshop and one of the machines, incorporating each of the systems, tools and human avatars so that the data can be viewed alongside their graphical representation. The University has provided the algorithms and data models for maintenance optimisation and shop floor input planning models.

Sistema de Rodaje



Estructura técnica



Sistema: 01. Rodaje	Actuación	Elemento de medición	IS1	IS2	IM
01.01-1	Parámetro de rueda	Altura P. < 36 mm	Rueda (RD)		
01.01-2	Parámetro de rueda	Espesor P. > 25 mm	Rueda (RD)		
01.01-3	Parámetro de rueda	Qr ≥ 6.5 mm	Rueda (RD)		
01-02-1	Diámetro de rueda	Tolerancia (840-760 mm) y visible la ranura	Rueda (RD)		
01-02-2	Diámetro de rueda	Check	Rueda (RD)		
01.03	Resalte exterior rueda	R.E.R. < 6 mm	Rueda (RD)		
01.04	Planos y aportación de metal	Planos y aportaciones ≤ 60 mm	Rueda (RD)		
01.05	Caras internas	Parte baja ruedas AR	Eje (EJ)		
		Parte baja ruedas AI	Eje (EJ)		
01.06-1	Caja de grasas	Estado de grasa	Caja de Grasas (CG)		
01.06-2	Caja de grasas	Verificación de rodamientos (antes del montaje)	Rodamiento (RT)		
01.06-3	Caja de grasas	Verificación de rodamientos (después del montaje)	Rodamiento (RT)		
01.07-1	Ejes	Check visual fisuras	Eje (EJ)		
01.07-2	Ejes	Check ultrasónicos fisuras	Eje (EJ)		

Documentos adquisición de datos

