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DIGIECOQUARRY
INNOVATIVE DIGITAL SUSTAINABLE AGGREGATES SYSTEMS

Horizon 2020 research and innovation programme (Nº 101003750)

Deliverable D1.3

Requirements for Quarry full digitalisation for Smart Sensors, Automation & Process Control, and for ICT solutions, BIM and AI report

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Deliverable report

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Disclaimer

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Table of contents

Deliverable report 2
Document Contributors 2
Document History 2
Disclaimer 3
Table of contents 4
List of Abbreviations 6
1 Executive Summary 7
2 Introduction 8
2.1 Concept/Approach 8
2.2 Deliverable objectives 8
2.3 Intended audience 9
3 Situations by site 10
3.1 VICAT 10
3.1.1 State 0 situation 10
3.1.2 To-be situation 10
3.2 HANSON 11
3.2.1 State 0 situation 11
3.2.2 To-be situation 12
3.3 HOLCIM 12
3.3.1 State 0 situation 12
3.3.2 To-be situation 13
3.4 CSI 13
3.4.1 State 0 situation 13
3.4.2 To-be situation 14
3.5 CIMPOR 14
3.5.1 State 0 situation 14
3.5.2 To-be situation 15
4 Requirements for the functionalities of the IQS - SMART SENSORS, AUTOMATION AND PROCESS CONTROL 16
4.1 Devices for automation of treatment plants and storage facilities 16
4.1.1 Requirements for the implementation of KTA 3.1 17
4.1.2 Use Case Description 21
4.1.3 Ma-estro's contribution in KTA3.1 21
4.2 Monitoring sensors and analysing tools for Mobile Machinery 23
4.2.1 Developments & Requirements 23
4.3 Mobile equipment & quarry geological deposit digitalisation & real-time modelling 24
4.3.1 Developments 24
4.3.2 Requirements for the implementation of KTA 3.3 25
4.3.3 Use Case Description 26
5 Requirements for the IQS interface platforms - ICT SOLUTIONS, BIM & AI 28
5.1 BIM Management & Connection 28
5.1.1 Developments 28
5.1.2 Data Exchange 31
5.1.3 Requirements for the implementation of KTA 4.1 33
5.1.4 Use Case Description 34
5.2 Artificial Intelligence (AI) algorithms 34

5.2.1 Developments 36
5.2.2 Requirements for the implementation of KTA 4.2 37
5.2.3 Use Case Description 39
5.3 Global Integration and IQS 43
5.3.1 Requirements for the implementation of KTA 4.3 43
5.3.2 Use cases description related to KTA 4.3 45
5.4 Business management tool 57
5.4.1 Requirements for the implementation of KTA 4.4 57
5.4.2 Use cases description related to KTA4.4 59
6 High level logical architecture design 61
6.1 Global IQS architecture 61
6.2 Data lake 62
6.2.1 Components diagrams for the Data Lake 62
6.3 IoT platform 70
6.3.1 Components diagram for the IoT Platform 71
6.4 Data Warehouse 79
6.4.1 Component descriptions of the Datawarehouse 80
6.4.2 Market analysis of datawarehouse implementations 81
7 Conclusions 84
8 References 86
9 Annexes 86
9.1 CSI comparison of the state 0 and the to-be situations 86
10 List of Figures 88
11 List of Tables 89

List of Abbreviations

Abbreviation	Description
AI	Artificial Intelligence
BIM	Building Information Management
BLOB	Binary Large Object
CA	Consortium Agreement
CFS	Certificate on the Financial Statements
CICD	Continuous Integration & Continuous Deployment
CIFS	Common Internet File System
DEQ	DigiEcoQuarry project
DNS	Domain Name System
DoA	Description of Action
EB	Exploitation Board
EC	European Commission
ETL	Extract Transform Load
GA	Grant Agreement
GDPR	General Data Protection Regulation
H&S	Health and Safety
HTTPS	HyperText Transfer Protocol Secured
ICT	Information and Communication Technology
IFC	Industry Foundation Classes format
IFS	Individual Financial Statement
IoT	Internet of Things
IQS	Intelligent Quarrying System
KPI	Key Performance Indicator
KTA	Key Technology Area
LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol
MoM	Minutes of Meetings
NFS	Network File System
PFS	Project Financial Statement
PRC	Project Research Committee
RP	Reporting Period
SaaS	Software as a Service
SMB	Server Message Block
SQL	Structured Query Language
WP	Work Package

1 Executive Summary

This document defines the requirements for the Intelligent Quarrying System (IQS) to be implemented in the frame of the DIGIECOQUARRY project.

The DIGIECOQUARRY project aims to gather the newest technologies and the most innovative digital solutions to boost the capacity of the quarries to meet the four main challenges that are the H&S and the security conditions for workers, the efficiency, the sustainability and the profitability of the processes but also of the resources and operations, and the social acceptance of stakeholders.

After an analysis of the current situation of the pilot sites regarding digitalisation ("state 0"), partners defined the requirements for the IQS related to:

the devices for the automation of the treatment plants and the storage facilities (control devices, sensors, robots) that will be designed and developed by MAESTRO and ARCO and implemented mainly on Vicat, Holcim and Cimpor sites,

the monitoring sensors and analysing tools for mobile machinery used in loading and transport (both internal and external) processes that will be developed by ABAUT and implemented on all pilot sites (excepted on CSI site),

the hardware and software used for the digitalisation of the mobile equipment done by DH&P on CSI site,

the acquisition of BIM models of the quarries (all pilot sites) in order to apply corresponding BIM technologies (schedules, 4D simulation, business intelligent reports, planning and estimation…) developed by APP,

the AI algorithms to be developed by SIGMA, supported by UPM-AI, in order to build predictive models to detect events and to generate alerts for all pilot sites,

the data lakes and the IoT platforms to be put in place by AKKA for all pilot sites in order to collect, store and process their data and then gather and provide this data, on request, to the data warehouse and to any other application or expert system that may need it,

the business management tool that should be considered within the IQS in order to allow the KPI monitoring of all the pilot sites.

All these requirements are associated to specific use cases that are also described in this document by key technology area for the different pilot sites.

Finally, a high-level logical architecture is designed in this document based on a first state of the art done on the data lakes, the data warehouses and the IoT platforms. This first results will be used for the execution of the benchmark to be implemented in task 4.1.

2 Introduction

2.1 Concept/Approach

The D1.3 deliverable is the main output of the Task 1.2, Requirements for Quarry full digitalisation (KTA 3 & KTA 4), run in the frame of the WP1, Requirements for a sustainable, social, safe, resource-efficient quarrying operation, co-led by AKKA and abaut GmbH, involving the following other partners: ANEFA, UPM, DH&P, ROCTIM, SIGMA, Ma-estro SRL, ARCO and APP Consultoría.

Within this Task 1.2, **ANEFA** has been the "**voice of the pilot sites**". ANEFA **visited each pilot site** and **shared** with all T1.2 involved partners all the relevant lessons learned, information and data from these visits.
In parallel, several **workshops** have been organized to allow **each partner** to **present its key technology area** and enable the **exchanges** on it with the rest of the involved partners.

Bilateral workshops have also been organized to **go deeply in the details** of each KTA between the **main involved stakeholders.**

These workshops allowed the partners to gradually **collect and define the requirements** and **their associated use cases** which are presented in this deliverable, but also to start to **design a high level logical IQS architecture**.

2.2 Deliverable objectives

The purpose of the **D1.3** deliverable is to **list the requirements** for the aggregates quarries full digitalisation. It addresses only the requirements covering the key technology areas (KTA) 3 (smart sensors, automation and process control) and 4 (Quarry full digitalisation through ICT solutions, BIM and AI)

Note that the requirements for other aggregates quarries' improvements are described in the following other deliverables (they are out of the scope of this document D1.3):

Table 1: List of the other deliverables of the WP1

Deliverable Number	Deliverable Title	KTA addressed
D1.1	Requirements for Improved extraction, rock mass characterisation and control report	*KTA 1*: IMPROVED EXTRACTION, ROCK MASS CHARACTERISATION AND CONTROL
D1.2	Requirements for Innovative Treatment processes	*KTA 2*: INNOVATIVE TREATMENT (CRUSHING / SCREENING / WASHING)
D1.4	Requirements for H&S improvement, Environmental impact minimization and energy and resources efficiency report	*KTA 5*: APPLICATIONS FOR HEALTH AND SAFETY IMPROVEMENT *KTA 6*: APPLICATIONS FOR ENVIRONMENTAL IMPACT MINIMISATION AND ENERGY EFFICIENCY

First of all, this deliverable **describes the current situation** of each pilot site ("State 0") as well as **the expected final situation** at the end of the project ("To-be"), with regard to their **level of digitalisation** and more precisely, to the following **key technology areas**: their use of smart sensors, automation and process control, ICT solutions, BIM and AI algorithms. Relevant indicators/KPIs to be delivered and the trends and levels to be achieved in each pilot site are also given in this section (3) of the deliverable.
Knowing that, this deliverable **details**, by KTA, the necessary **requirements** to reach each site's objectives and, beyond them, to propose a relevant **Intelligent Quarrying System (IQS)** to be disseminated in the sector of aggregates quarries. The related assumptions and constraints and the involved stakeholders are detailed in the sections 4 and 5 of this deliverable. **Descriptions of the use cases** in which these requirements will be useful are also written in these sections.

Finally, rich with all this information on the requirements and use cases, this deliverable **presents** what could be **the architecture of the IQS**, explaining, in the section 6, the **network infrastructures**, the **interactions between the different technologies** (geo-radars, radars, drones, thermal cameras, digital cameras, sensors, mobile phones, tablets, wearables, robotics, etc.) AI, BIM, Digitalisation, IoT, expert systems, sensors, and machines (drilling, loading (backhoes, excavators, loaders), transport (dumpers), bulldozers) and the **data communications** and **database structures** to be used by the IoT Platform interconnecting the data lake and the data warehouse.

2.3 Intended audience.

The **dissemination level** of this deliverable is **public**.

This deliverable is a **mandatory input** for the tasks to be done mainly in the frame of the **WP3** (development of sensors, automation and process control [KTA3]) and **WP4** (Development of an integrated IoT/ BIM/AI platform for smart quarrying [KTA4]).

3 Situations by site

An evaluation of the initial starting infrastructure and services (state 0) of each pilot will be done in WP1 to ensure fair measurement. The information is confidential and hosted in the DEQ repository.

3.1 VICAT

3.1.1 State 0 situation

The current situation of *Fenouillet* regarding digitalisation is:

- Wifi Related
  - Network coverage: 4G and 5G
  - WIFI network quality: Good, with potential internal restrictions
  - WIFI areas: Good, with potential internal restrictions
- Process Related
  - SAP system
  - Automatic water consumption measurement will be available when the new development is installed
  - Track and trace system for processes and products:
    - SIGMA
    - ISO 9001, CE marking of aggregates.
  - ERP
- Digital Equipment
  - Twice a year drones are subcontracted for stock control
  - Mobile phones with PTI function

3.1.2 To-be situation.

The improvements planned for this pilot are the following:

- KTA2.1 An innovative mobile crusher
- KTA3.1 Automation Software, Electrical connections and Production System
- KTA3.2 Monitoring sensors and analysing tools, Recognition system for workers
- KTA4.1 BIM
- KTA4.2 AI Algorithms
- KTA4.3 IQS
- KTA5.1 H&S recognition system.
- KTA6.1 Environmental simulation platform
- KSA7.1 Public acceptance
- KSA8.1 Communication with policy makers

3.2 HANSON

3.2.1 State 0 situation

The current situation of *Valdilecha* regarding digitalisation is:

- Wifi Related
  - Network coverage: WIFI
  - WIFI network quality: Poor
  - WIFI areas: Office

- Process Related
  - Geoposition. Yellow Machines equipped with sensors (provided by abaut)
  - SAP systems
  - Automatic fuel consumption measurement
  - Capture realtime process and event data
  - Remote/autonomous operation of the equipment
  - Track and trace system for processes and products
  - Track and trace system for explosives and detonators
  - ERP
  - Data management
  - IoT
  - PLC/DCS models
  - Communication method

Workshop workers have a mobile phone to monitor the condition of the machinery. With an application, they follow their maintenance periods, both predictive and corrective. Also, the application shows the workshop's stock level, so this way they never run out of supplies.

Dumper, excavator, etc. drivers use another application to measure daily production. Every time a cycle is completed, they must register it, thus production is accurately followed up.

The Heidelberg Cement Group has invested a lot to develop an integrated digital web-based tool for the management of all the sites of the company. They are able to know on real time a number of KPIs to follow the site management. This information is compiled at group level with different levels of integration.

- Digital Equipment
  - Radars: Plant automation.
  - Drones to survey stocks and extraction area.
  - Mobile phones: All FTE ere equipped with smart phones for data input (maintenance system, start/end time, activity, asset utilisation, fuel consumption, cycle time, number of trips to destocking, etc.
  - Tablets: Plant availability, start/end times, cycle times.
  - PCs.

- Laptops.

3.2.2 To-be situation.

The improvements planned for this pilot are the following:

- KTA4.1 BIM
- KTA4.2 AI Algorithms
- KTA4.3 IQS
- KTA5.1 Health and Safety recognition system
- KTA6.1 Environmental simulation platform
- KSA7.1 Public acceptance
- KSA8.1 Communication with policy makers

3.3 HOLCIM

3.3.1 State 0 situation

The current situation of *HOLCIM - Pioltello San Bovio* regarding digitalisation is:

- Wifi Related:
  - Network coverage: Ethernet Swisscom/Fastweb
  - WIFI network quality: None
  - WIFI areas: None
  - Other: External 4G

- Process Related:
  - SAP systems
  - Weighbridge truck scaling (D800 + Log on) that works also in automatic.
  - Automatic fuel consumption measurement (for Liebherr weel-loader)
  - Plant Data management and control (SCADA)
  - PLC/DCS models
- Digital Equipment:
  - Mobile phones
  - Alone workers devices
  - PCs
  - SENSORS & DEVICES
  - Level sensors on deposit silos
  - Rotation sensors in conveyor belts

- Anti-stucking sensors in conveyor belts
- Absorption measurement in crushing systems
- Weigh in conveyor belt.

3.3.2 To-be situation.

Solutions to be applied:

KTA2.2 Models for crushing and screening optimization.

KTA3.1 Production Control System and Automation

KTA3.2 Monitoring sensors and analysing tools + Recognition system for workers: ABAUT.

KTA4.1 BIM: APP

KTA4.2 AI Algorithms: SIGMA + UPM AI

KTA4.3 IQS: AKKA

KTA5.1 Health and Safety recognition system: ITK

KTA6.1 Environmental simulation platform: CHALMERS

KSA7.1 Public acceptance: ZABALA

KSA8.1 Communication with policy makers

3.4 CSI

3.4.1 State 0 situation

The current situation of *CSI - Mammendorf* regarding digitalisation is:

- Wifi Related:
  - Network coverage overall: About 40% of quarry and site area
  - WIFI network quality: good quality for data transfer
  - WIFI areas: Storage yard, product loading area, parts of the extraction/quarry area

- Process Related:
  - Geoposition: Some mobile machines are fitted with geo position in their OEM online systems. Often the onboard-GPS is not precise enough, and the geo position data is sent in long intervals so that data cannot be used.

    A TomTom system is installed on each truck. Evaluation possibilities are low. GPS data is often not precise enough. Based on Google Maps. System is developed for road trucks.
  - Automatic truck scaling: 3 quarry trucks are fitted with an OEM or after-market scale to optimize average loading/transport amounts.
  - Automatic fuel consumption measurement: Fuel station and internal fuel truck is fitted with the same measurement and evaluation software, that yields machine and driver specific consumption data.
  - Capture real time process and event data: SPS production plant control software.

  - Track and trace system for explosives and detonators: TTE System. 3D-modeling software for blasting process with GPS-referenced
  - 3D-LaserScanner technology
  - Nowadays production measurement method:
  - Combination of weight-scale data (on mobile machinery, on conveyer belts, outbound weight-bridge), and cycle-numbers

- Digital Equipment
  - Radars: Level measurement and back control on wheel loaders as a safety equipment
  - 1 mobile thermal camera
  - Digital cameras
  - Mobile phones
  - Tablets
  - PCs
  - Laptops
  - Not feasible to give every worker a smartphone.

3.4.2 To-be situation.

Solutions to be applied:

KTA3.3: Mobile equipment digitalization, real time modelling & data: DH&P

KTA4.1 BIM: APP

KTA4.2 AI Algorithms: SIGMA + UPM AI

KTA4.3 IQS: AKKA

KTA6.1 Environmental simulation platform: CHALMERS

KSA7.1 Public acceptance: ZABALA

KSA8.1 Communication with policy makers

3.5 CIMPOR

3.5.1 State 0 situation

The current situation of *AGREPOR - Alenquer* regarding digitalisation is:

- Wifi Related:
  - Network coverage: Administrative office
  - WIFI network quality: Good
  - WIFI areas: Administrative office

- Process Related

  - SAP GUI: They have an automated plant control system, which displays each machine and its status. This system is controlled from the plant's guardhouse but can be viewed from anywhere.
  - Automatic truck scaling: Cachapuz SLV
  - Automatic fuel consumption measurement
  - Track and trace system for explosives and detonators
  - PLC/DCS models
  - Communication method

- Digital Equipment:
  - Digital cameras
  - Mobile phones
  - Tablets
  - PCs
  - Laptops

3.5.2 To-be situation.

Solutions to be applied:

KTA3.1 Packaging optimization, Automation Software + electrical connections for storage optimization and improvement of OOE: MA ESTRO + ARCO

KTA3.2 Monitoring sensors and analysis tool for mobile machinery for internal and external transport optimization: ABAUT.

KTA4.1 BIM: APP

KTA4.2 AI Algorithms: SIGMA + UPM AI

KTA4.3 IQS: AKKA

KTA6.1 Environmental simulation platform: CHALMERS

KSA7.1 Public acceptance: ZABALA

KSA8.1 Communication with policy makers

4 Requirements for the functionalities of the IQS - SMART SENSORS, AUTOMATION AND PROCESS CONTROL

4.1 Devices for automation of treatment plants and storage facilities

Develop treatment plant affects main process system. This system production begins with raw material reception which makes a direct connection *with internal transport fleet*, in the other hand, this interface is a direct connection with *the storage process*.

Table 2: Treatment plant stages

Diagram for a treatment plant	
1-Raw material reception	The material is measured in the Hopper reception by radar/ weigh cell or camera beside a weight scale
2-Feeder Mill / Crusher	To send the material from Hopper reception to mill is normal to use a feeder to control its speed through shifter frequency. We can use in this point different sensor to avoid obstruction and stops; it increases time work
3-Mill, Crusher, Grinder	The mill is controlled with a shifter frequency which permits us to control the motor torque getting higher performance
4-Belt Conveyor / Gravity	These are the usual way to transport material in a treatment plant from a machine to other
5-Screener	The vibrations screener separates the stone in different size through the meshes. In a quarry there are different screeners to get a wide variety of sizes
6-Pile / Hopper / system storage like bigbag/packaging or direct transport to customers	After separate the different stone size in the primary process it can be repeated by secondary even tertiary sector until to get the size needed. It is possible using a softer mill and a finer screener in each stage

Regarding aims from KTAs, the treatment system based in PLCs (Program logic control) and SCADA (Graphical interface) through the expert system can be able to generate in near real time the data of measures the most important consumption and production. This technical work can send to IQS the needed data for an effective analysis.

4.1.1 Requirements for the implementation of KTA 3.1

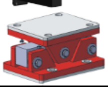
Here are ARCO's requirements for the implementation of the KTA3.1 on Vicat and Holcim pilot sites:

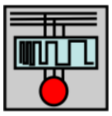
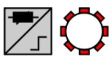
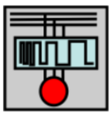
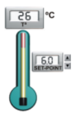
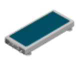
Table 3 List of the requirements for KTA3.1

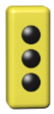
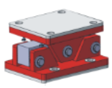
ID Requirements	Requirements descriptions
T1.2_KTA3.1_1 (Data from Arco system / Data Lake)	Format, frequency, and communication protocol to send and receive the data will be defined in order to enable data exchange with external systems (Maestro scada system)
T1.2_KTA3.1_3 (N. º Machine with single operation)	This machinery does not have a specific control only on/off, but it is possible to get some signal of alarm when they break down. It is necessary to connect Arco System to electrical control cabinet
T1.2_KTA3.1_5 (N. º Machine with completed control)	This machinery has a specific control including consumptions of energy, measure of production, signal of warning and alarm when they break down. it is necessary to install additional equipment
T1.2_KTA3.1_7 (Input data sensor)	Input data from consumption of direct and variable order machinery: Energy, water, etc… This signal is implemented to send to Data Lake with the format and frequency required. The sensors have to be compatible with modbus TCP
T1.2_KTA3.1_9 (Input data sensor)	Input safety control from certain machines. Signal of warning and alarm when the conditions are true. Stop Machinery, stop the process. Sensor compatible with modbus TCP
T1.2_KTA3.1_11 (Measure Water)	Water consumption from direct and recycle sources. It can be measured by weight or volume
T1.2_KTA3.1_17 (Output data to IQS)	Exportation of the most relevant data: Weight of the different products, energy consumptions, alarm, machinery work time. Format, frequency and communication protocol to send data

Here is the list of the sensors that will be deployed on Vicat and Holcim sites to set up an automation solution:

Table 4 List of the sensors for KTA3.1.

Source/Sensor		Sensor Location (machinery)	Level (Primary/Secondary/Tertiary/Al)	Description/Application (input)
weight sensor From Data Lake Manual (AP-04-DG):		Scale truck	Primary Secondary *Tertiary*	Quantity of raw material to be process Weight detection in large volume hoppers. Range up to 250 tons with application similar to Vision Camera and Radar Sensor
Radar, weigh, and video (AP-DG-02) (AP-DG-07) (AP-DG-03)		Hopper Reception	Primary Secondary Tertiary	Level or weight in hopper reception Kilograms / tones/ % Capacity

Source/Sensor		Sensor Location (machinery)	Level (Primary/Secondary/Tertiary/AI)	Description/Application (input)
Shitfer frequency (AP-DG-05)		Motor Feeder	Primary Secondary *Tertiary*	Control feeder with feedback from mill, Crusher or Grinder Hertz, Rpm, Volts, Amps, Watts
Bridge weighting in belt (AP-DG-07)		Belt material processed or waste belt	Primary Secondary *Tertiary*	Material processed belt Kilograms / Tones
Band deviation (AP-DG-06)		Belt material processed or waste	Primary Secondary *Tertiary*	Warning / Alarm of belt material waste Sound and light or system warning
Rotation sensor (AP-DG-08)		Belt material processed or waste	Primary Secondary *Tertiary*	Warning / Alarm of belt material waste Sound and light or system warning
Shitfer frequency y/or Network Analyser (AP-DG-05)		Motor Mill, Crusher, Grinder	Primary Secondary *Tertiary*	Control Mill, Crusher or Grinder. Hertz, Rpm, Volts, Amps, Watts, % Torque Motor
Network AnalyseR (AP-DG-11)		Distribution panel	Primary Secondary *Tertiary*	General parameters of electrical consumption for group of machines or individual
Pressure sensor (AP-DG-10)		Hydraulic group	Primary Secondary Tertiary	Hydraulic group for Mill, Crusher or Grinder Pa (Pascal) N/m^2 or Bar ATM
Temperature sensor (AP-DG-10)		Hydraulic group	Primary Secondary Tertiary	Hydraulic group for Mill, Crusher or Grinder Degrees Celsius
Metal detector (AP-DG-12)		Input material band	Primary Secondary *Tertiary*	Warning / Alarm of belt material Sound and light or system warning

Source/Sensor		Sensor Location (machinery)	Level (Primary/Secondary/Tertiary/AI)	Description/Application (input)
Radar, and video (AP-DG-02) (AP-DG-03)		Storage hopper for processed product	Primary Secondary *Tertiary*	Material level processed into final hopper (For different products)
Radar, and video (AP-DG-02) (AP-DG-03)		Storage hopper for processed product	Self-service truck loading system (For different products processed)	Self-service truck loading system (For different products) m^3 and/or % Capacity
Signal from botton panel (AP-DG-15)		Storage hopper for processed product	Self-service truck loading system (For different products processed)	Self-service truck loading system (For different products) m^3 and/or % Capacity
Video (AP-DG-03)		In the plant access	Automatic vehicle control	Delivery note: identity truck number
Weight sensor From Data Lake Manual (AP-04-DG)		Scale truck	Automatic vehicle control	Delivery note: Automatic truck weight

The final list of the sensors will have to be finalized and validated with the involved partners and the pilot sites.

The digitalization enables the generation of the following outputs/KPIs:

Table 5: Treatment Plant KPIs

Requirement and KPI´s for each stage treatment plant. Power supply is necessary to the sensors.		
Requirements for KTAs	Stage	KPIs / Output
Radar / Weigh cell / video	1-Raw material reception	m^3/h or Tn/h Raw material received. We can warn when Hopper is full
Shifter frequency	2-Feeder Mill / Crusher	Control Speed feeder with feedback from mill to increase the performance. This way it is possible to forecast the Treatment plant capacity percentage. (From 0% to 100%)
Network analyser	3-Mill Crusher	Energy consumption kw/h Control torque

Shifter frequency	Hammer	Performance optimization
Metal detector Continuous weighing system Rotation sensor /material detector	4-Belt / Conveyor or Gravity	Avoid breakdowns. Time off Tn / h Production and Tn/h Waste Avoid vacuum work and save energy
Level sensors put in the output to avoid obstructions	5-Screeners	Increase continuous work time and avoid the stops
Radar / weigh cell / video	6-Pile / Hopper / bigbag/packaging or transport.	Tn / h Production of different products type, including waste

The following picture depicts how identified sensors will be used.

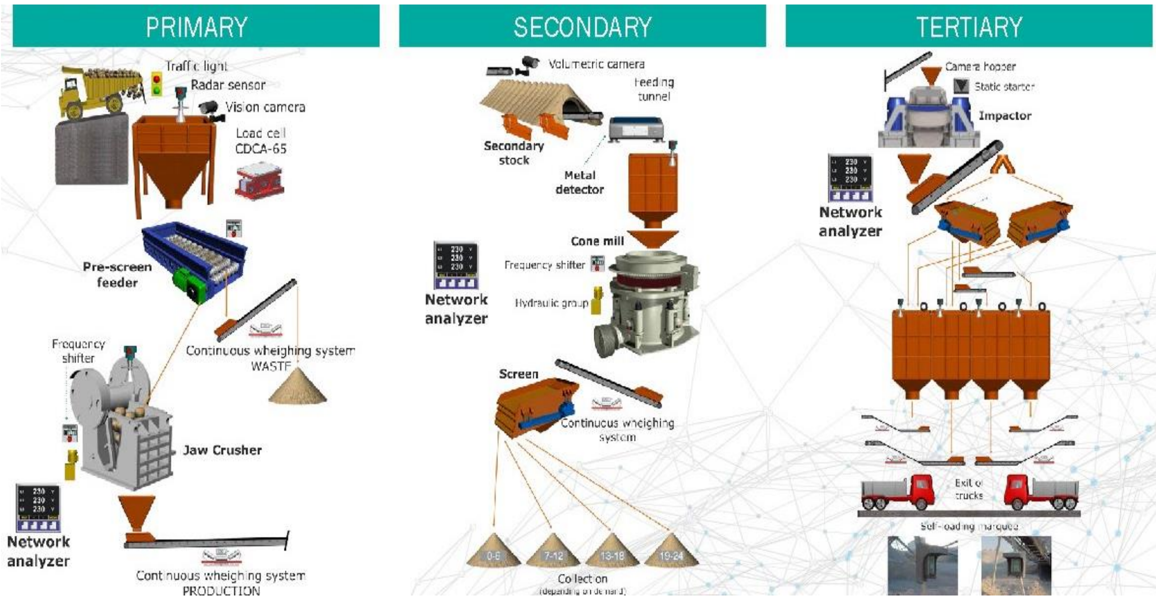


Figure 1: Sensors view in a treatment plant.

Here are the main outputs:

Table 6:Machinery List and Deliveries

Outputs	Detailed data and features
Consumptions: ▪ Water ▪ Oil ▪ Electricity ▪ Fuel	▪ List of the machinery to look up. ▪ Sensor from the consumption source to PLC ▪ Choice to the power supply operate. (External, by battery) ▪ Used units
Production: ▪ Final products ▪ Wastes	▪ Type the products finished. ▪ Quantity ▪ Quality ▪ Relation between products and waste
Transmission	▪ Choice the transmission data way. (By cable, Wi-Fi, Gps...) ▪ Choice type data to storage
▪ Another point	▪ Time started/stopped machinery. ▪ Time machinery down / break ▪ Time loap / unloap ▪ Maintenance and planned shutdowns

4.1.2 Use Case Description

Here are ARCO's Use Cases Descriptions:

Table 7: Use Case

Use Case Description	Explanation
Improve Machinery Performance	▪ Review the stop time machinery. ▪ Analysis of non-productive activities ▪ Identification low performing machinery. ▪ Stop (If it is possible) the empty machinery material as belts, screws and feeders
To get lower waste	▪ Secondary feedback systems ▪ Choice to highest effective machine/way for different materials
To get lower energy consumption	▪ To know the energy consumption by main treatments part of plant: Primary, Secondary… ▪ To know the energy consumption of the most important machinery plant: Hammer Mill, main feeder, bigs screws…
To know relation between production and consumption from different treatments track	▪ ARCO Experts System can provide access to data sheet and graphs

4.1.3 Ma-estro's contribution in KTA3.1

Ma-estro is a company specialized in control and automation systems for crushing plants (stationary, mobile and operating machines).
Its experience in this market comes from its born directly from quarries environment. In this project DEQ, once received the signals and data from ARCO (as said at begin), the PC will send the data by internet connection or by modem with a Sim data by protocol HTTPS to the Maestro's server cloud, where will be elaborated and prepared to resend them after then on a datalake in base of query's request.

The Ma-estro's added value is the chance to offer a web app (portal web) with a user-friendly interface, concepted for quarry's workers where is possible to connected by any device (smartphone, tablet or pc) with a simple internet connection. The data will be transmitted every 5 minutes.

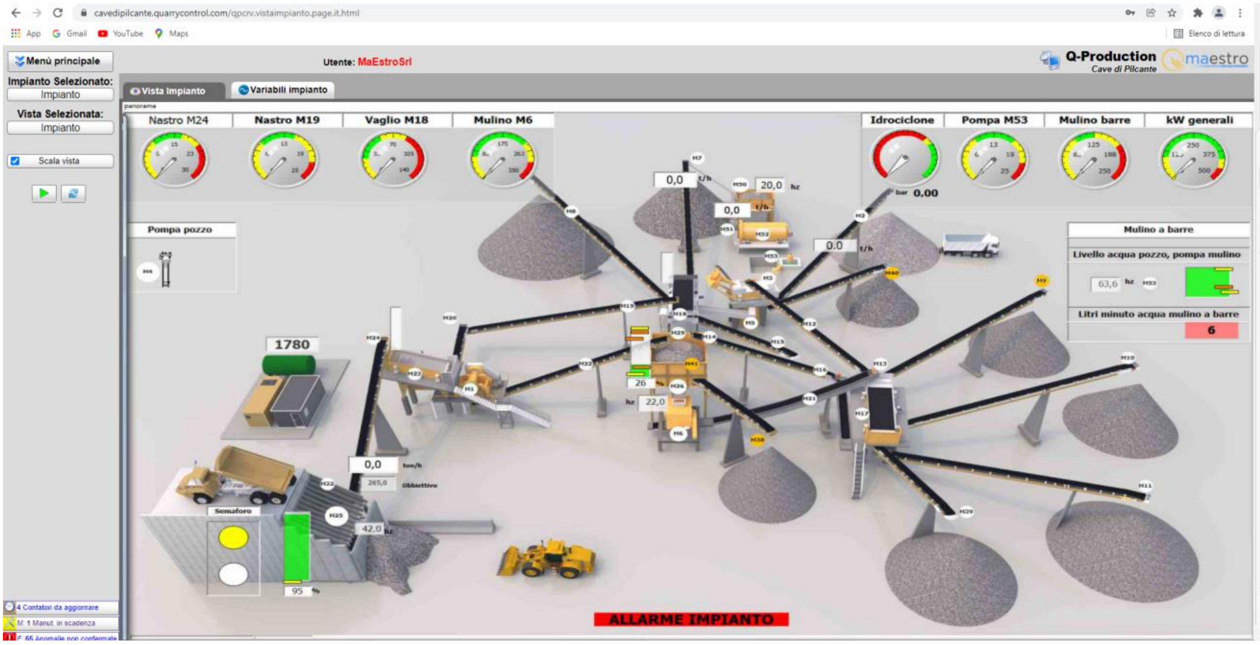


Figure 2: Plant view by remote in real time

Furthermore, it can see the status of the plant in real time and thanks to this program it can monitor data and information as: production (tons or volume), energy consumptions, fuel consumes, alarms and events, batch management, maintenances, working times (start, stops, idle etc...) and so on in base of the implemented sensors.

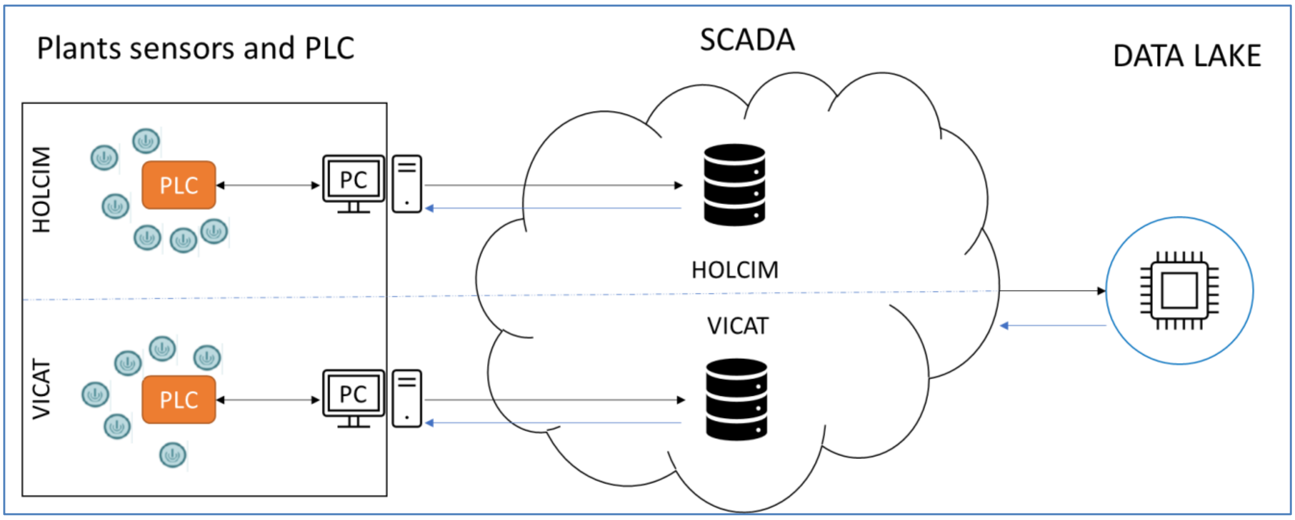


Figure 3: Logical scheme for data transmission

For both plants (Holcim and Vicat) will be implemented a PLC to receive and manage all signals thanks to field bus. The PLC communicates directly with an industrial PC and through an internet connection send the data to the Maestro's cloud (one for each site). At the end these data will be elaborated in base of the queries and will be forwarded to datalake.

4.2 Monitoring sensors and analysing tools for Mobile Machinery

4.2.1 Developments & Requirements

Regarding the mobile machinery fleet, abaut will focus on the following applications.

- Traceability between the extraction and the treatment plant, including external transport.
- Integrated management of the truck fleet, including environment & safety aspects
- Automatic generation of materials' reports
- Real-time positioning of mobile quarrying equipment
- Recognition system for workers nearby mobile quarrying machines
- Recognition system for workers in specific locations

Below, in Figure 4 & Figure 5 is possible to see in detail the hardware of abaut for developing the activities mentioned above.

Figure 4: sView - mView

Figure 5: abaut Edge

Requirements for the implementation of the KTAs

Table 8: KTA Requirements

Requirements	Explanation
Power supply for the sensor unit	The system of abaut requires power supply for working, in order to operate, a 12/24V energy supply is needed
Mobile and Stationary machinery list	List of the Mobile and Stationary Equipment with Characteristics [e.g., year, nominal capacity, brand, model, working hours, Km, type of tyre] in excel format
Aerial Image of the quarry	Map or 2D image for visualization and monitor options in GeoTIFF format and georeferenced
Delineation of relevant working (quarry, fuel station, workshop, crusher) areas	Definition of the surface of the working areas in the mine incl. definition of loading/unloading areas, places of fix installed material output
Connectivity for data transmission	Needs of 2G-3G-4G connectivity in the mine in order to transmit the information collected

KPIs & Use Cases Description

Table 9: List of KT A & KPIs

KPIs & Use Cases Description	Explanation
Optimize Machinery Performance	Analysis and monitoring of the mobile machinery KPI's for optimizing the fleet efficiency and mining mobile machinery performance [e.g., cycle times, machinery in operation, etc.]
Automation of the info-flow	Status report of the quality and mass flow extraction [e.g., t/h, loading-unloading areas, etc.]
Minimization of the Non-production	Identification of the non-productive activities and inefficiencies [e.g., idle times, unneeded driving, etc.]
Recognition system of persons & equipment	Monitor, in near real time, the position of mobile machinery to improve the safety workers. Recognition of workers nearby of the mobile equipment by identification of the persons by mobile camera [mView]. Deployment of camera system in the processing plants for process detection requirements.
KPI's and data needed for drill to mill	Report and analysis of the KPI's for the D2M concept [e.g., loading performance, hauling routes, etc.]
KPI's and data needed for Integrated H&S and environmental systems	Report and analysis of the KPI's for Integrated H&S and environmental systems [e.g., hauling distances, remediation activities, etc].

4.3 Mobile equipment & quarry geological deposit digitalisation & real-time modelling

DH&P develops mobile equipment & quarry geological digitalization & real-time modelling in KTA 3.3. The development will take place in two main areas, the hardware and the software for mobile equipment digitization.

The development of an original equipment manufacturer (OEM) independent solution to record, monitor and analyze mobile machinery data is of great interest to a large number of stakeholders. Stakeholder who would particularly benefit from such a development are.

- Management board
- Quarry manager
- Workshop/Maintenance crew
- Machine operators
- Occupational safety officer
- Environmental protection officer

4.3.1 Developments

In detail, DH&P will pay particular attention to the following areas during development:

- Monitoring system for mobile equipment data (loading and hauling machinery) independent from the manufacturers.
- Integrated management of the mobile equipment (loading and hauling machinery), including environmental & safety aspects
- Automatic generation of mobile machinery reports
- Real-time positioning and mapping of mobile equipment
- Material traceability between the extraction points and the primary crusher

- Geofences to monitor actions and interactions of mobile equipment and material transport.
- The developments will take place as part of DHP's expert system *smart. Quarry/AutoPLAN* which has a corresponding data interface with the IoT.

DH&Ps expert system *smart.Quarry/AutoPLAN* is integrated in the pilot CSI.

Figure 6: Datalogger

4.3.2 Requirements for the implementation of KTA 3.3

Table 10: Requirements for the implementation of KTA 3.3

Requirements	Explanation
The expert system must work with CAN Bus data from different OEMs	Most quarries consist of mixed fleets with machines from different OEMs. Smart Quarry will develop a solution to collect and analyse data independently from the OEM
The expert system must record data from different sensors equipped on the mobile equipment using a data logger	The machine data will be collected with a data logger from the CAN Bus that is originally installed on the machine and connects the different sensors/machine units (e.g., engine control unit etc.)
The expert system must pre-process data from different sensors equipped on the mobile equipment using a data logger	The data must be pre-processed on multiple levels to avoid data redundancy, reduce data transmissions and allow analysing. First data pre-processing will be handled on the data-logger level
The expert system must transmit the recorded data from each mobile equipment to a server on site via mobile network or WLAN	Data from all equipped mobile machinery is collected on a server on site. The transmission can be via mobile network, an installed WLAN network or M2M communication. A central hub for data exchange between the machines and the server on site could be located at the pre-crusher
The expert system must transmit the recorded data from the pilot to the analysing platform	Data from the server on site are transmitted to the analysing platform (cloud)
The expert system must combine data from mobile equipment with additional manual input data	The application should offer the possibility to insert for example target values to compare these to analysed KPIs from the machine data
The expert system must provide real-time kinematic positioning of the mobile equipment	Real-time kinematic positioning is important for several KPIs and also health and safety aspects

Requirements	Explanation
The expert system must provide the fuel consumption of each mobile equipment	Fuel consumption is one of the most wanted KPIs as fuel consumption is a major cost factor
The expert system must provide the activities performed of each mobile equipment	Monitoring of activities like loading, hauling, idle time
The expert system must provide the status of each mobile equipment	Monitoring of the machine's status (on/off)
The expert system must integrate 3D geofences to link the mobile equipment position with its activity	3D geofences are used for material tracing, health and safety and activity tracking
The expert system must provide production from mobile equipment	Monitoring of the production of each machine, overall production, comparison of differences in productivity
The expert system must provide driving speeds of mobile equipment	Driving speed can be used to evaluate road conditions, use of machines, speed limits (health and safety)
The expert system must provide distances driven by the mobile equipment	Distances can be used to evaluate process optimization
The expert system must provide tire pressure of mobile equipment	Tire pressure is an important value in terms of wear and reduction of maintenance costs
The expert system must provide tire temperature of mobile equipment	Tire temperature is an important value in terms of wear and reduction of maintenance costs
The expert system must provide the engine operation mode of mobile equipment	Evaluation of the machine handling; reduction of maintenance costs
The expert system must the determine cycles performed of mobile equipment	Evaluation of productivity of the fleet and single machines
The expert system must provide time stamp for each recorded data	Every recorded data set need a unique time stamp to assign and match sensor data to each other
The expert system must record gear usage of mobile equipment	Evaluation of the machine handling; reduction of maintenance costs
The expert system must record engine and general alerts of mobile equipment	Evaluation of the machine handling; reduction of maintenance costs
The expert system must validate data recorded and analysed	Internal validation function

4.3.3 Use Case Description

Table 11: Use Case Description of KTA 3.3

Use Case Description	**Explanation**
Monitoring of the machine position on exchangeable background (maps, orthophotos etc.)	The connection of the vehicle's location and adaptable orthophotos and mine maps is required to adapt with the visualisation to the successive changing quarry environment (haul roads, benches etc.) and enable the quarry management to connect a certain recorded event to a defined location within the quarry
Monitoring of the fuel consumption of mobile machinery in different relations (consumption per ton, consumption during idle times or working etc.)	The fuel consumption is a major KPI in mining and must be monitored in different relations (e.g., litres per ton) and combinations (litre per day per machine etc.). It allows comparison of the machine handling, maintenance status (tire pressure etc.) or the machine efficiency itself
Monitoring of the status of the machine	Monitoring of the working and downtimes of each mobile machine allows the calculation of predefined efficiency rates and comparison with defined target rates.

Use Case Description	Explanation
Monitoring of the material transport between defined locations within the quarry	The quarry workflow can be followed along the path of the material allocated in machine operations. To understand the quarry process in depth all material streams must be recorded and comprehensible. This includes for example the transport from the production bench to the pre-crusher, the transport from the production site to the dump, the material from the overburden bench to the dump, the transport from the plant site to a stockpile to the pre-crusher or the transport from the pre-crusher to the dump (fines)
Documentation of the maintenance history of machines	The maintenance history including installed and ordered spare parts and spare part identification, repairs completed, machine maintenance plans, scheduled and unscheduled maintenance
Visualization on a map of the hauling speed of the mobile machinery filled and empty	The hauling equipment speed will be visualized on a map to identify random speed changes of the machines (demand for haul road maintenance)
Visualization of a heat map of movements	The drive paths of the machines will be visualized to identify bottle necks and points of intense vehicle movements
Monitoring of the driving distances loaded and empty	All driving distances must be monitored to evaluate the quarry design and conducted changes for optimization in drive distances (e.g., ramps, benches, drive ways etc.)
Tire management (tire pressure, tire temperature, lifetime)	Tires are a cost factor in mining and early detection of low tire pressure or failure can prevent damage and therefore reduce costs
Monitoring of the loading-, dumping-, and idle time	The working time of each machine must be analyses to further analyse the effective production time of each machine
Monitoring of the scale data of mobile machines	The scale system provides the mass loaded or hauled by each machine and is one of the most relevant parameters in the quarry workflow
Monitoring of the used operation modes of the mobile machines (power mode, eco mode)	The different operation modes of each machine can be used to evaluate the right machine handling
Monitoring of the cycle number for loading and transport of each mobile machine	The number of cycles can be used for performance comparison and is and production KPI within the quarry operation
Monitoring of the cycle time (each and average) per mobile machine	The time required for one cycle (loading at the production bench, driving loaded to the pre-crusher, dumping, driving empty to the production bench) is used to evaluate operational changes
Monitoring of the engine speed of every mobile machine and the gear used	The engine speed and gear used is monitored, connected speed and altitude change over time the handling of the machine can be evaluated
Monitoring of internal warnings of the mobile machines	All internal warnings of the machines must be monitored
Monitoring of ton-kilometers per hour per machine	Combination of speed and mass transport as an important KPI for comparison between quarries or operational set ups
Monitoring of the machine cooperation (which loader loaded which truck)	The loading cycles must be monitored including the machine cooperation between excavator/wheel loader and dump truck to evaluate if machine combinations set ups are sufficient
Effectivity index	Different efficiency indexes based on predefined production coming from the quarry management must be calculated individually
Visualization of position and duration of events on a map (idling, warning, loading, dumping)	All events must be correlated to the machine position and visualized on adaptable backgrounds
Warnings if invalid data	The recorded and analysed data set must be evaluated for data consistency and plausibility, evaluating data loss and transmission issues.

5 Requirements for the IQS interface platforms - ICT SOLUTIONS, BIM & AI

5.1 BIM Management & Connection

APP will be applying and developing BIM process in DEQ project in KTA 4.1. In DEQ, BIM will benefit in Mining and Quarry Planning development and in BIM Lifecycle Quarry Data Management.

The lifecycle information management occurs not in one software or database (it's impossible to build a solution that would be equally good at all parts). The only way to actually do it is to create an integrated system of applications, where data is interoperable, and it all becomes a working environment that keeps your data live, accurate, and allows us to perform useful analytics. Expert System connects to these applications and provides them with the unified Asset Information Model.

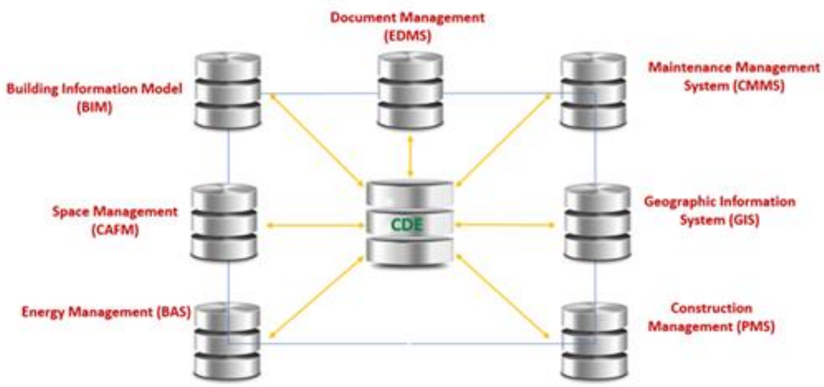


Figure 7: Example of the lifecycle information management diagram

5.1.1 Developments

Benefits of the **BIM in Mining and Quarry Planning Development** are 3D visualization of the project, clashes/conflicts visualization, time planning and works execution optimization as well as resource and cost optimization. It includes project portfolio management, project timeline optimization and general process of planning and scheduling with 3D BIM Model. Information data from Data Lake will be used in mass haulage planning that will refer to time-location planning.

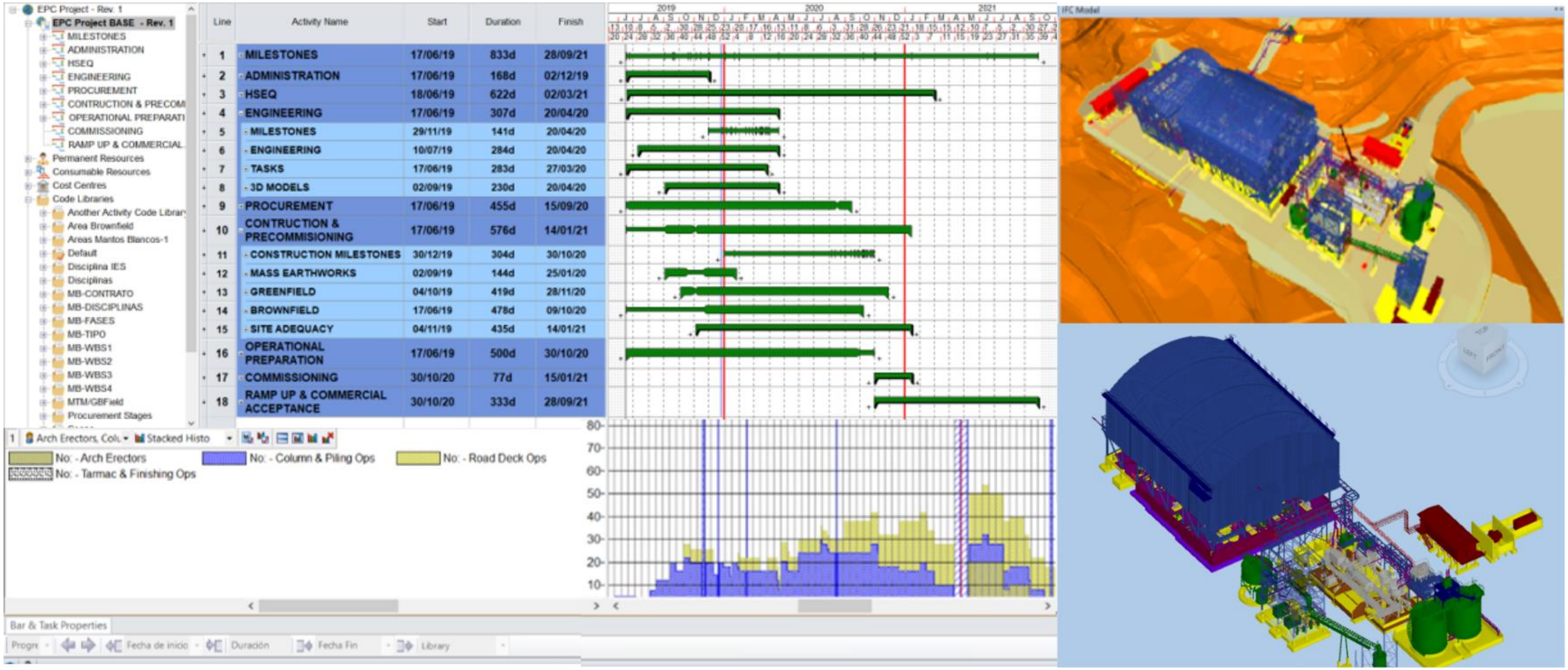


Figure 8. Example of Mining and Quarry Planning

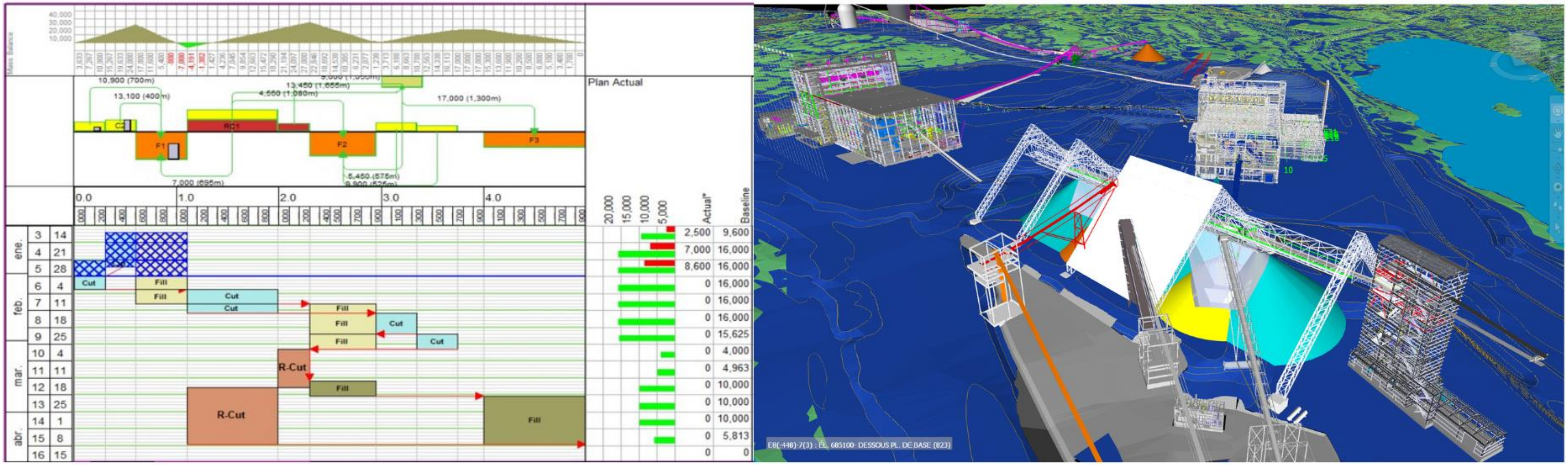


Figure 9. Example of Mining and Quarry Planning including Time-Chainage Planning

Benefits of **BIM Lifecycle Data Management** is more explicit and more complex at the same time. To reach the goal of creating Digital Twin it will require integrated information from BAS/IoT, CMMS, FM, and GIS systems.

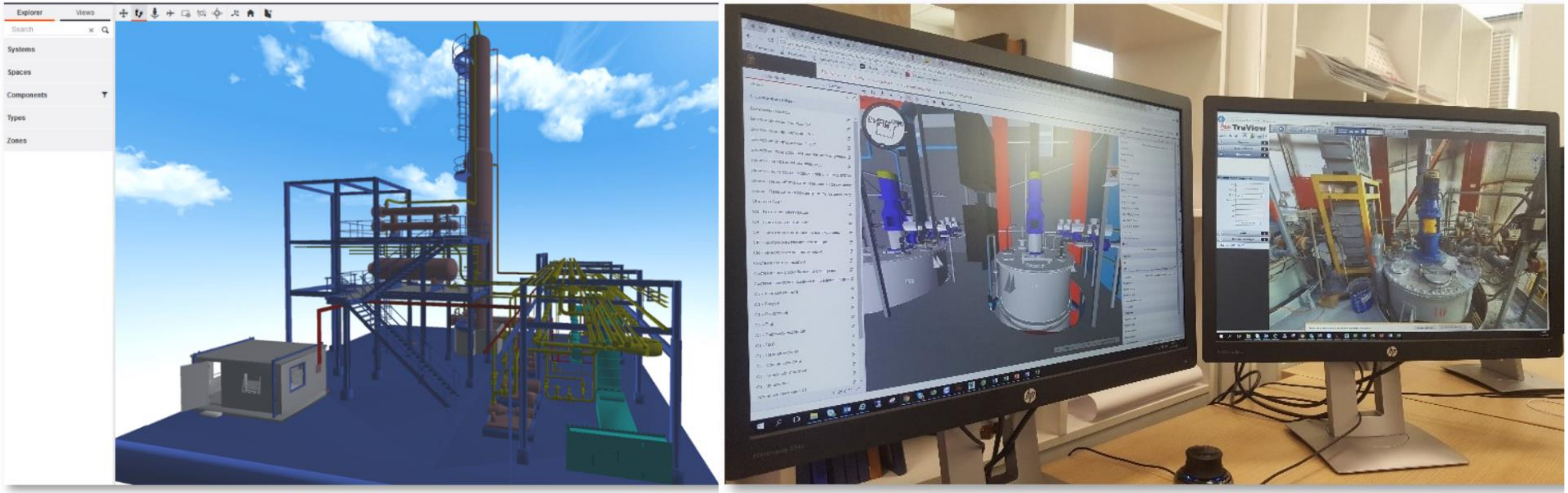


Figure 10. Example of BIM lifecycle Data Management

5.1.2 Data Exchange

Data Exchange in BIM will be carried out by custom created APIs (Application Programming Interface), as well as Open industry standard formats such as IFC (Industry Foundation Classes), OmniClass and COBie (Construction Operations Building Information Exchange) which is special developed international standard to make data exchange and manage assets information. It is closely associated with BIM process.

ne	atedBy	atedOn	Category	Description	etType	nufacturer	delNumber	rrantyGuarantorParts	rrantyDurationParts	rrantyGuarantorLabor	rrantyDurationLabor	rrantyDurationUnit	System	Object	Identifier	placementCost	pectedLife	ationUnit	rrantyDescription	ninalLength	ninalWidth	ninalHeight	delReference	ape	e	or	ish
Se	Ca	202	23-85 50 17 11	Junction Boxes - Data_Sensor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	23-85 50 17 11	Junction Boxes - Data_Sensor CR2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	92e	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Co	Ca	202	n/a	Ducts_Conveyor Belt	n/a	Co	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	568	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ha	Ca	202	n/a	Ducts_Hanson Instalations	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	568	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ha	Ca	202	n/a	Walls_Hanson Equipment_Office 01	n/a	n/a	n/a	n/a	10	n/a	n/a	n/a	Aut	Ifc	8bc	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ha	Ca	202	n/a	Walls_Hanson Equipment_Secondary Tre	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	39b	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ha	Ca	202	n/a	Walls_Hanson Equipment_AP	n/a	Sa	n/a	n/a	3	n/a	n/a	n/a	Aut	Ifc	643	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ha	Ca	202	n/a	Walls_Hanson Equipment_Aux 04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	643	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ha	Ca	202	n/a	Walls_Hanson Equipment_Aux 01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Aut	Ifc	01e	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

ne	atedBy	atedOn	TypeName	Space	scription	System	Object	Identifier	ialNumber	tallationDate	rrantyStartDate	Number	Code	etIdentifier	a	gth
Se	Ca	202	Sensor	Office 01	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	Sensor	Office 01	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	Sensor	Secondary Treatmen	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	Sensor	Secondary Treatmen	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	Sensor	Secondary Treatmen	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	Sensor	Secondary Treatmen	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Se	Ca	202	Sensor	Secondary Treatmen	n/a	Aut	Ifc	6f1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Name	atedBy	atedOn	egory	etName	RowName	Value	Unit	System	Object	Identifier	scription	owedValues
Actual Lighting Load	Ca	202	Ap	Sp	Stockpile	n/a	W	Aut	Aut	-11	n/a	n/a
Actual Lighting Load per area	Ca	202	Ap	Sp	Stockpile	n/a	W/m²	Aut	Aut	-11	n/a	n/a
Actual Power Load	Ca	202	Ap	Sp	Stockpile	n/a	W	Aut	Aut	-11	n/a	n/a
Actual Power Load per area	Ca	202	Ap	Sp	Stockpile	n/a	W/m²	Aut	Aut	-11	n/a	n/a
Area	Ca	202	Ap	Sp	Stockpile	5083.1218	SqMeter	Aut	Aut	-10	n/a	n/a
Area per Person	Ca	202	Ap	Sp	Stockpile	28.5714	SqMeter	Aut	Aut	-11	n/a	n/a
Base Finish	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Base Lighting Load on	Ca	202	Ap	Sp	Stockpile	-1	n/a	Aut	Aut	-11	n/a	n/a
Base Offset	Ca	202	Ap	Sp	Stockpile	-8.1598	Meter	Aut	Aut	-10	n/a	n/a
Base Power Load on	Ca	202	Ap	Sp	Stockpile	-1	n/a	Aut	Aut	-11	n/a	n/a
Calculated Cooling Load per area	Ca	202	Ap	Sp	Stockpile	n/a	W/m²	Aut	Aut	-11	n/a	n/a
Calculated Heating Load per area	Ca	202	Ap	Sp	Stockpile	n/a	W/m²	Aut	Aut	-11	n/a	n/a
Calculated Supply Airflow per area	Ca	202	Ap	Sp	Stockpile	n/a	L/(s·m²)	Aut	Aut	-11	n/a	n/a
Category	Ca	202	Ap	Sp	Stockpile	Rooms	n/a	Aut	Aut	-11	n/a	n/a
Ceiling Finish	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Comments	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Computation Height	Ca	202	Ap	Sp	Stockpile	n/a	Meter	Aut	Aut	-10	n/a	n/a
Department	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Design Option	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Export to IFC	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Export to IFC As	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Family Name	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a
Floor Finish	Ca	202	Ap	Sp	Stockpile	n/a	n/a	Aut	Aut	-10	n/a	n/a

Figure 11. Example of COBie exchange in BIM

5.1.3 Requirements for the implementation of KTA 4.1

Table 12: Requirements for implementation

Requirements	Explanation
3D Model of projects	3D Models are required to start working on the BIM Process and Integrations and Connection we well as maintain it in the Common Data Environment. Any 3D model of quarries including all discipline systems, Architectural, Structural, Mechanical and Engineering, Plumbing, Electrical etc. Recommended to have LOD 400 or LOD 500 (Level of Development)
Work amounts, resources, productivity rates should be in Data Lake	Information, like work amount, resource usage, productivity rates from Data Lake will be taken into the consideration when planning site works
4D BIM Planning for the mining and quarry planning improvement	The expert system must integrate work planning schedule associated with 3D BIM Models to create 4D BIM Schedule that will improve mining and quarry planning.
The expert system must have location planning diagrams and mass movements diagrams	Location Planning and Mass Haulage Schedule must be created based on the data from Data Lake. Mass movement schedule is one of the critical aspects that need to be improved using advanced expert systems.
The expert system must be enabled for Data Exchange	3D Model data exchange must be in IFC file format. Other data integration will be covered by OmniClass and COBie (Construction Operations Building Information Exchange) standards. Special developed APIs (Application Programming Interface) will make integration between other expert systems.
The expert system should integrate and deploy 3D laser scanned assets	The critical assets might be required to perform 3D Laser scanning and point cloud. Those data will be integrated in the expert system along with 3D BIM model
The expert system must enable to link existing asset databases to the 3D model	List of the assets must be provided in OmniClass and COBie formats for the interconnection with the 3D BIM model in expert system
The expert system should enable to link existing technical documentation to the model	Existing technical documentations will be associated with assets and elements in 3D BIM Model for better navigation and information about the asset and element
The expert system should provide access to mobile application	Mobile usage in BIM will provide the ability to navigate around the 3D model with possibility to monitor the issues, workflows, and orders. Special expert application needs to be installed
The expert should integrate with GIS application	GIS application should be integrated with 3D model for easy access of geo location of particular asset. Need to identify which current GIS system pilot projects are using
The expert must integrate with CMMS/CAFM application	During the BIM implementation, integration between Maintenance Management systems (CMMS) is required to help to get assets information. It will provide asset name, serial number, maintenance information and installation date and so on. Need to identify which CMMS systems is currently deployed in the projects in order to make proper connections between systems
The expert system must be connected to the BAS/IoT data.	Need to determine which software's and protocols are going to be used. As well as which assets are connected to sensors. Moreover, time range for the synchronization need to be determined
The expert system must be connected to documents.	Integration of documents with the assets will help to easily identify all information related to the particular assets during the check-ups and issues
The expert system must define and configure the user access rights.	Expert system will restrict the access to the particular data based on the user types and rights. This will allow to avoid any unauthorised changes in the system

5.1.4 Use Case Description

Table 13: Use Case Description

Use Case Description	Explanation
3D Models are required to start working on the BIM Process and Integrations	Analysing available 3D BIM models and drawing new 3D assets to improve the 3D Model if necessary. Recommended BIM uses for LOD 400 and LOD 500
Work Planning Schedule Improvements	Implementing more advanced solutions with the integration of 3D model and improving site work planning schedule using productivity rate, resources and work amounts data from Data Lake and 3D BIM models properties
Mass Haul Planning Schedule	Optimization timing and resource usage and creating location planning diagrams, mass movements diagrams and comparison between planned and actuals
BIM Common Data Environment (CDE)	Common Data Environment (CDE) is a collaborative environment where all the stakeholders in a project share the data. It is used to collect, manage and disseminate documentation, BIM-driven workflows, and processes whilst managing both site and office teams. Expert system will provide CDE
3D Laser scanning	In complex project with plenty of mechanical, electrical, and plumbing system lack of detailed models, 3D laser scanning might be required for critical asset.
BIM and GIS integration	Integration GIS with BIM will provide direct view where the particular project facility or part is and will give the ability to go inside the model and see related elements
BIM and BAS/IoT Integration	Integration BIM and BAS/IoT will help us to see the data directly from the assets that will be connected to the sensors and help to analyse the data from the asset that will be collected by particular period of time
Maintenance Management systems (CMMS)	Maintenance Management systems (CMMS) will be integrated with assets during the BIM implementation, and this will help to get asset information like, Name, Location, Serial Number, Installation date etc in the expert system
Mobile usage in BIM and Quality Control	Mobile usage in BIM will help to navigate around the 3D model with the asset information and will provide the ability to find the asset, mark up the documents, manage issues, create work orders, forms
Document Management Integration with BIM	Assets and elements will integrate with related document and documents will associate with its categories, tags and version etc. All documents can be accessible via mobile and web application using barcode scanner, searches or 3D model elements
Digital Twin by integration 3D BIM Models	A digital twin is a virtual model designed to accurately reflect a physical object. The twin is constructed so that it can receive input from sensors gathering data from a real-world counterpart. This allows the twin to simulate the physical object in real time, in the process offering insights into performance and potential problems

5.2 Artificial Intelligence (AI) algorithms

Artificial Intelligence (AI) will be used to close the circle around the optimisation of a digital quarry. This will allow the information to be an asset in economic, environmental or human terms since it will automatically evolve and improve over time.
AI will be divided into six main phases: 1) Information analysis and filtering; 2) Design of the algorithm: modelling based on the available information and the technical restrictions required; 3) Algorithm training: optimisation process of algorithm parameters; 4) Industrial architecture design: definition of a computational architecture according to the needs of the use of the algorithm (real-time, resilience to errors, algorithm access networks, etc.); 5) Testing of the algorithm: checking in a real environment for final implementation; 6) Coordination and iteration: control of all objectives and integration of phases, synergies, etc.

SIGMA supported by UPM-AI team, including UVa, has to develop quarry applications in order to optimize, monitor and help in the decision-making processes, based on the use of Artificial Intelligence algorithms and modelling. In order to do that data will have to be gathered, then pre-processed in order to train models. The Artificial intelligence algorithms will be mostly based on the use of Deep Neural Networks (DNN). The results will be stored on a data warehouse, in order to be accessed by dashboards. The principles of the architecture to be developed are presented in the following diagram:

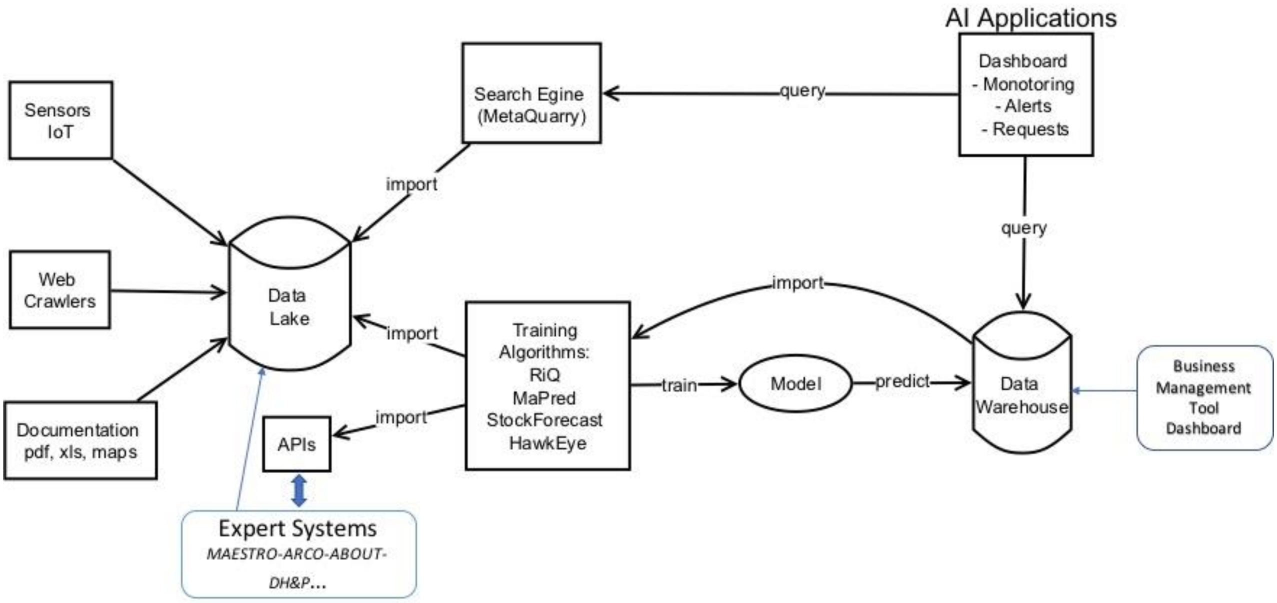


Figure 12: AI principles architecture

The AI algorithms will be implemented on a specific environment, most probably on a cloud server (easier to maintain, deploy and provide SOTA secure, maintainable and resilient solution). Most of the data will be extracted from the “data lake” of each quarry. Data formats will be diverse and will have to be pre-processed in order to guaranty its quality for the training processes of the models that will be implemented for the applications listed in section 5.2.1. The data pre-processing step will be based on:

- Data filtering
- Data annotation
- Data labelling
- Metadata processing
- Etc.

The results of the AI services/algorithms will be fed to the Datawarehouse where only analysed and processed usable data will be stored.
The Stakeholders who can profit from the AI application features are:

- Quarry Management board
- Quarry COO
- Workshop/Maintenance crew
- Machine operators
- Occupational safety officer
- Environmental protection officer
- Urgency services (Firemen, police, Ambulance/Health (nearby hospital/112)
- Third parties: Transport services, Customers

There will be close coordination between Sigma, UPM-AI and UVa for the development of the AI algorithms. This will require periodically revisions of the characteristics and data received (periodicity, replicability, etc.) indicated in WP3. There will also be coordination with APP for the management of the Project. The idea is that a researcher will coordinate and organise the development of the AI algorithms and control the usefulness and validity of the models obtained before being stored in the Datawarehouse. Also, there will be a supervision of the flux of data between the "data lake" for each quarry, the AI predictive models and the data warehouse.

5.2.1 Developments

The applications that will be developed by SIGMA supported by UPM-AI team, including UVa, around Artificial Intelligence services for the quarries are:

- **RiQ: Risks detection** around the operations on the quarries. The most important objective of this application is to prevent accidents and abnormal behaviour and help the quarry managers to take action on different elements of the quarry that due to the changing conditions, need to be modified or immediate action has to be triggered. For example: the roads for the transport of material and machinery may eventually present changes or characteristics that can cause an accident (unevenness, narrowing, flooding, proximity of machines in the quarry, etc…). It will determine the optimal work structure, avoiding personal risks and will be useful to validate the KPI's of the productivity of the workers and to correct potentially risky situations. In brief, the main goal is to increase security of the quarry operations followed by social acceptance. The RiQ algorithm would be developed by testing the implementation of the DNN with quarry input data.
- **PrMa:** Provide information to act upon **predictive maintenance** operations, in order to minimize the maintenance and increase the lifetime of the machines. The AI algorithms in this case will be able to detect Abnormal operations and predict possible failures of machines. To calculate the probability of failures, the useful life (time)after a failure and to provide alarms that signal the quarry personnel about the need of repair or maintenance operations. The aim is to reduce operation costs and increase efficiency. PrMa would be developed by testing the implementation of the CDNN with quarry input data.
- **Stockforecast**: Help the quarry managers to **manage the production stocks**, managing information about customer demands, market prices, optimal handling of orders, prediction of production needs that will lead to stock handling, etc…… Future requests along with a time-horizon window will be predicted. Thus, the main objective is to predict the optimal amount of stock of aggregates to produce in order to improve the efficiency of the quarry and prevent from overstock, understock and wasted energy and time. StockForecast will be developed by testing the implementation of the CDNN with external and internal quarry input data.
- **Metaquarry**: Will be a service that will allow to classify, search and obtain the relevant information pertaining to a given quarry. The information will be stored in a secure environment normally belonging to the quarry. The information can be of almost any type: Video, files, text, audio, voice recordings. The result will be and specialized advanced search engine and information classification engine, using Natural language processing as input in order to provide in a very efficient way results from complex query inputs (sentences, word combinations, etc.). The search engine will search instantly information about user manuals of machines, mine maps, protocols, PRL documents, etc. The idea is that the information could be accessed from any device, fixed or mobile. The main goal is to compare and improve the infrastructures and processes in the quarries. MetaQuarry would be developed by testing the implementation of the DNN and NPL techniques with quarry input data.
- **Hawkeye**: This application will be using computer vision technology, extracting information from videos and images obtained from the quarry:
  - Drone flights
  - 3D quarry images from BIM
  - Satellite images

- Etc…

The result of the image analysis will be in the form of calculation of volumes, measure of distances, quality of material analysis, security alarms, etc… The objective is to detect in real-time possible changes in quarry surface, and also to predict the geometrical differences along time. HawkEye would be developed by testing the implementation of the CDNN with quarry satellite/drone raster and vector data.

5.2.2 Requirements for the implementation of KTA 4.2

Table 14: Requirements for the implementation of the Artificial Intelligence services

Requirements	Explanation
Static Information from the quarries should be stored/sent to the iQS Datalake using a standard query API as soon as the information is generated by the quarry. Data formats can be open but should be clarified in WP4 with the quarries	Many data will come from IT and administration systems from the quarries which is stored and modified at different intervals. This information does not come from sensors or machinery from the quarries, it is generally provided by the Quarry personnel
AI applications environment will have to process data coming from the Datalake and thus the needed interfaces should be put in place	The data lake will store all the information relevant to the project coming from various sources. This data in many formats will be accessed by the AI Application environment via APIs and queries
The AI application environment must pre-process data from the Datalake	The data must be pre-processed on multiple levels to avoid data redundancy, increase de data quality and provide metadata used for appropriate AI models training and algorithm optimisation. Data pre-processing may start at the Datalake level depending on the function available on the latter
RIQ1: Information about the mobile equipment should be made available through the expert systems (Datalake/sensors): Positioning, Speed, Load, Process ID, Characteristics (Make year…), Operation hours, Accidents, failures, Last maintenance operation	Data from all equipped mobile machinery must be made available to the AI environment through the data lake or expert system APIS or though the IOT platform
RIQ2: Information about the workers in the quarry should be made available through the expert systems (Datalake/sensors/Mobile apps): working hours, schedule, positioning, yearly progress, outsourced or in-house, age, years of experience, last training, hours worked last seven days	Various type of information from quarry workers must be made available to the AI environment through the data lake or IOT Platform. The workers information should be made available to the AI environment via the data lake in any form provided at the end by the quarries (text files, CSVs, SAP APIs, etc…)
RIQ3: Weather, atmospheric, vibrations local conditions information on the quarry should be accessed by the AI environment through the datalake or internet services	Local weather information and Ambient sensor information (Local platform for measuring dust, CO2, wind, humidity, etc.) should be accessed by the AI environment, through the data lake or internet services
RIQ4: 2D, 3D images and videos should be made available to the AI environment in order to deduce possible Risks in precise locations of the quarries	The image or video data should be made available via the data lake to the AI environment to have spatial information about the quarries. The use of cameras is to be analysed case by case
RIQ5: Alarms may be generated by the service sending instantaneous information via email, instant messaging platform or any means available on the quarries working framework	The AI environment should put in place a messaging service to signal important risks in a timely manner. The alarms that are not time critical will be made available through the AI dashboard
MQ1: The MetaQuarry AI service will have to search for information very specific for each and every quarry that will have to be fetched from the Datalake	Metaquarry is a specific, Natural language driven, searching tool for the quarries. Some of the information will have to be shared directly from the Quarries databases or IT environment of each quarry. An interface will have to be defined to the Datalake
MQ2: The MetaQuarry AI service should be able to extract information from the BIM environment about specific details from each quarry like geographical, physical, types of machines used (providers and sources of information)	Metaquarry can also search information from the BIM environment via an API

Requirements	Explanation
MQ3: The MetaQuarry AI service should be able to extract information from the Expert systems available on each and every Quarry	Metaquarry should be able also to search for information from the expert systems, when not available on the Datalake
MQ4: The Metaquarry AI service must have the possibility to rank its answers depending on user programmable parameters	Metaquarry AI search engine will provide a list of results ranked using given parameters. Similar to what is done by the internet navigators
MQ5: The Metaquarry AI service must have a Secure Web Based interface accessible from mobile and fixed devices	Metaquarry will have a web interface that could be accessed from mobile and desktop devices
MQ6: The Metaquarry AI service will be able to perform searches on every specific Quarry via an interface that will have authorization and identification features	Metaquarry AI driven search engine is targeted to be an information gathering and classification tool specific to each specific quarry. Some of the information will possibly not be public and thus Metaquarry should be able to function for each quarry information environment independently
MQ7: The Metaquarry AI service should be given access to specific information coming from the Quarry providers. This may be implemented via the data lake	For the Metaquarry algorithm access may be needed to external quarry information systems belonging to third parties interacting directly with the quarry (Transport companies, customers, equipment providers, etc…)
PM1: Equipment information from each quarry should be accessible by the predictive Maintenance AI service, whether coming from the given supplier expert systems and/or the quarries Datalake instances	The Predictive Maintenance AI service will need all the information pertaining the maintenance and operation of the quarry equipment. It may be extracted by the AI environment via each of the instances of the Datalakes or via APIs directly linked to the equipment supplier databases
PM2: Similar to RiQ5, Alarms may be generated by the service sending instantaneous information via email, instant messaging platform or any means available on the quarries working framework	The AI environment should put in place a messaging service to signal important maintenance information in a timely manner. The alarms that are not time critical will be made available through the AI dashboard
PM3: The PrMa AI service may also extract information about the Quarries machinery from the BIM instantiations	An API should be made available to access any related information about the equipment used in the quarries, its operation and manuals in the BIM tool
PM4: The PRMa AI Service should get access to Real Time information coming from sensors	Real time Information coming from sensors (IoT Platform If not provided by the Expert Systems already) would be also needed to evaluate the performance of the equipment and verify if predictive maintenance operations are needed
PM5: The PRMa AI service would need the following equipment related information/Data: Noise, Vibration, temperature, ultrasound, speed, load, year of fabrication, last revision/maintenance made, Type of operations performed on the quarry, failures history, manuals	The list provided in this requirement is the minimum set of information. It would be interesting to plan for the provision of additional sensors if some of this information would not be provided by the equipment expert systems
SF1: The StockForecast AI service will need to get historical quarry cost metric from each of the quarries from the Datalakes	The Stock Forecast AI service will be analysing the material produced by each quarry its quality and cost along time in order to be able to make predictions
SF2: The StockForecast AI service will need to get historical Production costs information via the Datalakes	The Stock Forecast AI service will be analysing the costs relative to the production of the material in the quarry. This to be able to help quarry managers to manage the stocks along time
SF3: The StockForecast AI service will need to get information from the mobile equipment about the handling of material including transport (within the quarry, and external transport from the quarry to the customer sites), extraction points, volumes, etc.	The StockForecast AI environment will need to get this information via the equipment expert systems and/or the Datalakes. This information will help StockForecast to make detailed predictions and analysis on how the stocks are managed in a quarry and help the quarry managers to improve the processes
SF4: The StockForecast AI service will need to get information from the quarry plants about the handling of material including crushing, washing, belt transport, volumes handled, material quality, etc.	The StockForecast AI environment will need to get this information via the equipment expert systems and/or the Datalakes. This information will help StockForecast to make detailed predictions and analysis on how the stocks are managed in a quarry and help the quarry managers to improve the processes

Requirements	Explanation
SF5: The StockForecast AI service will have to get information from the transport of the material to the customer sites (external)	The StockForecast AI environment will have to get the information from the Datalake which will be getting the information from the quarry site or via the interface to other system managing information of the material loading and external transport operation
SF6: The StockForecast AI service will need market information about the materials handled on the quarry: market prices, historic sales, the demand in the market, the possible customers, the actual customers, satisfaction polls...	The StockForecast AI environment will need to get this information for every market that is relevant for the quarry connected to the IQS system (country, region, specific customers, etc…). The Datalakes will be the most suited store to get the information from
HE1: The Hawkeye AI service is based on the use of Computer Vision Technology able to analyze images from various sources, therefore enough image and video data will have to be made available	The AI environment will need to get the image and video information via the available interfaces or the Datalakes coming from cameras installed in the quarries, mobile equipment, drone flights, 3D models for BIM, etc.
HE2: The quality and point of view for the image data will have to be agreed upon with the quarry sites in order to get valuable information	The Hawkeye will need quality images in order to implement the needed analysis from the quarries: the analysis can be based on Security analysis in order to detect risks for workers and equipment, on the analysis of the quarry grounds about material quality, about the historical exploitation surface and rehabilitation procedures
HE3: The Hawkeye AI service will need to get prefiltered image data inputs implemented on the expert systems	In order for the analysis of Hawkeye to be effective, the image data to be fed will have to be pre-processed and selected to obtain better results. This pre-processing will have to be implemented previously by the Expert systems the cameras are connected to or in the Datalakes or if that is not possible at the AI environment itself
HE4: It will be necessary to get data from the Datalakes, internet services, and Geographical/Geological Surveys	The AI will need data about the area affected by extractive operations every year and from the past years in order to predict the evolution of the surface affected by quarry operations. Likewise, the data about restored areas through time will be necessary. It will be possible to obtain data from satellite images

5.2.3 Use Case Description

Table 15: Artificial Intelligence services use cases.

Use Case Description	Explanation
RiQ detects a significant increase in the probability of a workplace accident in the quarry. Risk levels: acceptable, moderate, high, extreme	**RIQ** is able to weight the possibilities of risks by analysing data constantly and will highlight which are the factors that are making the risks more evident. It will signal where the Risk can occur and designate the process and possible equipment that are susceptible of provoking a hazard
RiQ determines the most relevant features that influence the increased risk: human factors, weather, environment, or equipment	
RiQ predicts the most frequent type of workplace accidents in the quarry and the most likely depending on current circumstances	
RiQ delimits the areas of the quarry where a workplace accident is most likely to occur depending on current circumstances	
RiQ generates alarms to be stored on the Datawarehouse and to be displayed on the RIQ Dashboard, for not urgent alarms	
RiQ is able to show on worker mobile devices via SMS / Instant Messaging that a risk has been detected	
MetaQuarry enables natural language searches for information relevant to quarry workers on a specialized search engine	**Metaquarry** provides the ability to execute advanced search services and in particular in this case with respect to workers of a given quarry finding out
MetaQuarry indexes documents from any written or audiovisual source for retrieval through the search engine	

Use Case Description	Explanation
MetaQuarry recommends semantically equivalent words or phrases to make searches easier for the users	critical information about their work schedules, specifications, type of jobs executed, skills, etc…
MetaQuarry displays statistics on the appearance of phrases or keywords in the database and highlights trending topics.	
MetaQuarry learns to rerank its results based on the actual use of the search engine by quarry workers	
PrMa detects anomalies in the normal operation of the quarry equipment	**PrMA** through its data processing algorithms is able to detect possible issues in the quarry equipment on its everyday functioning or signal the users of a given maintenance activity that has to be performed.
PrMa diagnoses which failure may be associated with the detected anomaly.	
PrMa determines the useful life of an equipment in which a failure has been detected.	
PrMa advises maintenance operators on the best solution to mitigate the failure.	
StockForecast predicts the client demand of aggregates	**StockForecast** analyses internal data from the quarry in terms of production and combines it with the information from the Aggregates market in the respective market of a given quarry. All this to allow quarry managers to plan for stocks provisioning in the quarry and make commercial decisions upon the information analysed by StockForecast on the markets.
StockForecast predicts the evolution of the price of aggregates	
StockForecast calculates the optimal stock level depending on the quarry facilities, the demand, the price of the aggregates and the cost of production	
Hawkeye displays different points of view of the quarry sites (chosen by the users)	**Hawkeye** analyses internal image data from the quarry and combines it with the visual information from the other databases. It also accesses Images from the 3D models obtained by the BIM instantiations of every quarry. Hawkeye includes image AI processing algorithms to be able to detect objects, people buildings etc in the images it processes. In such a way that changes in the different quarry scenarios can be highlighted.
Hawkeye displays graphs on how the surface of the quarry has changed over time	
Hawkeye displays graphs with zone alarms in order to plan for a better exploitation and planning of points of extraction	

Below a representation of the main AI use cases is appended:

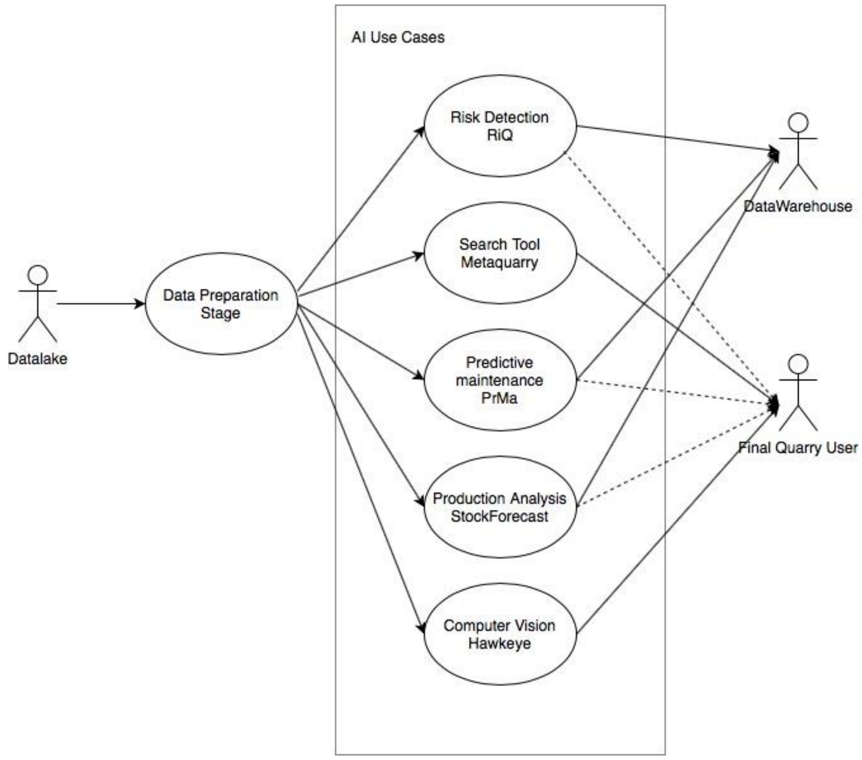


Figure 13: Use cases overview regarding the AI Services (KTA 4.2)

5.2.3.1 Risk detection use case diagram

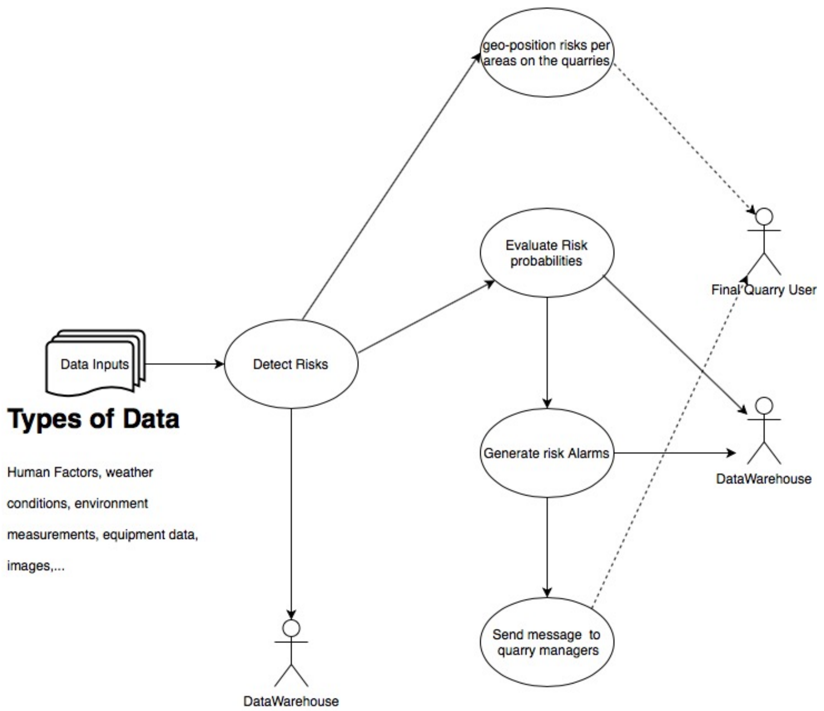


Figure 14: Risk Detection (RiQ) use case diagram

5.2.3.2 Predictive Maintenance (PrMa) use case diagram

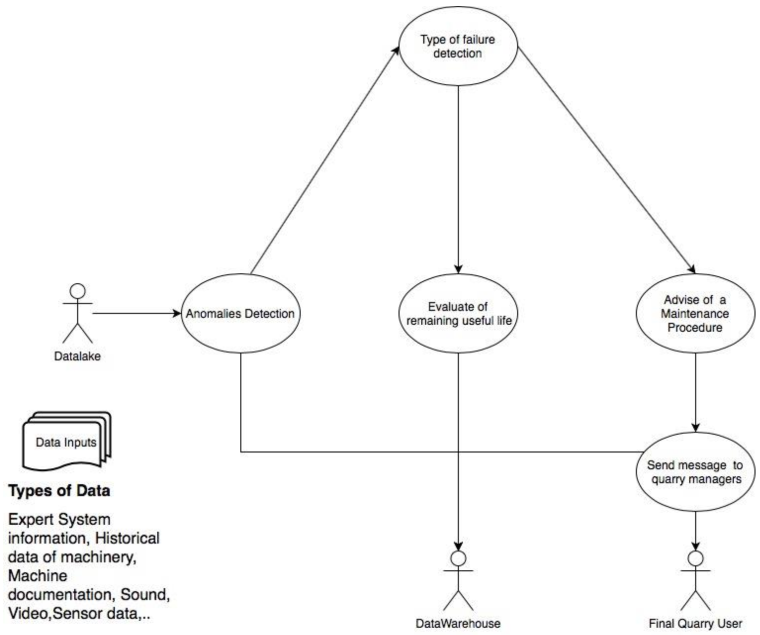


Figure 15: Predictive maintenance (PrMa) use case diagram

5.2.3.3 Metaquarry Use Case Diagram

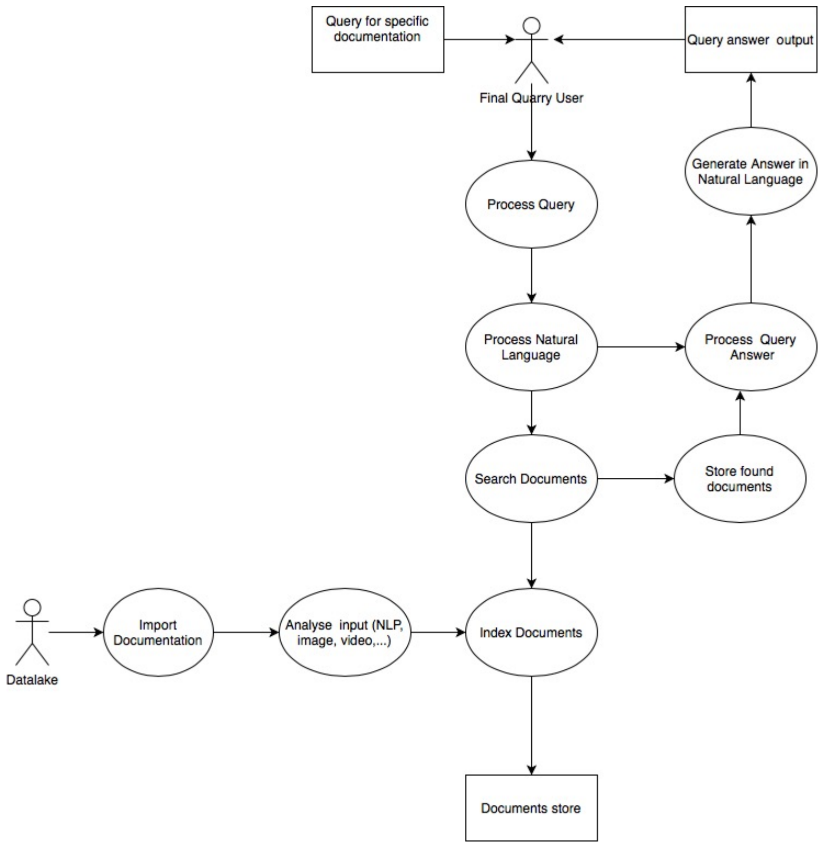


Figure 16: Metaquarry use case diagram.

5.3 Global Integration and IQS

The global integration and the IQS implementation led by AKKA mainly consists of the deployment of a data lake and an IoT platform. It also consists of the development of connectors allowing accesses, in the cloud, to other components of the IQS such as the BIM, AI models, a data warehouse and several applications as well as the expert systems and sub-platforms on the field.
As a consequence, and according to their dedicated requirements and uses cases, this global integration and the IQS will concern the five pilot sites of the DigiEcoQuarry project, Vicat, Hanson, Holcim, CSI and Cimpor. The global integration will involve the following partners, in addition to AKKA team:

- APP, for the **BIM** (refer to section 5.1)
- SIGMA and UPM-AI, for the **AI models** and the **data warehouse** (refer to sections 5.2 and 0)
- ANEFA, UPM, MUL and CHALMERS as well as the IT teams of the pilot sites for the **applications**:
  - **Business management** tool (refer to section 5.4)
  - **H&S** Management tool
  - **Environmental** Management tool
  - **Social Acceptance** Management tool
  - **Expert systems and sub-platform** of pilot sites (refer to section3)
- All technical providers of different **sensors, devices, mobile equipment, including their corresponding tools and data sources** on pilot sites:
  - ARCO and MAESTRO, for devices for automation of treatment plants and storage facilities (refer to section4.1)
  - ABAUT, for monitoring sensors and analysing tools for mobile machinery (refer to section 4.2)
  - DH&P, for mobile equipment, quarry geological deposit digitalisation and real-time modelling (refer to section4.3)

5.3.1 Requirements for the implementation of KTA 4.3

Based on the DR1 and on the requirements and use cases descriptions of the pilot sites and partners (in this document), here is the list of the **requirements related to the global integration and the IQS.**

Table 16: List of the requirements for the global integration and the IQS

ID Requirements	Requirements descriptions
Functional requirements	
T1.2_KTA4.3_1	The IQS should ensure the full end-to-end connectivity of workers and machines with information management platforms
T1.2_KTA4.3_2	The IQS should comply to the following requirements: the flexibility of the system, the scalability, the replicability, as well as the ease of deployment and the user-friendliness.
T1.2_KTA4.3_7	The IQS should provide access to external web and mobile applications (aggregating of georeferenced data with the aim of raising general awareness and alerting about environmental and security hazards that may need improvements around quarrying operations (citizen grade monitoring of operations))
T1.2_KTA4.3_8	The IQS should deploy an IoT Platform to collect data
T1.2_KTA4.3_9	The IQS should deploy a datalake to store its data
T1.2_KTA4.3_11	The IQS should integrate the BIM tools (Exchange format IFC files)

ID Requirements	Requirements descriptions
T1.2_KTA4.3_12	The IQS should integrate AI based tools
T1.2_KTA4.3_13	The IQS should have a dashboard that displays data linked to KPI to be computed in the different pilot sites
T1.2_KTA4.3_15	The IQS should enable the connection with process control of all the quarry processes
T1.2_KTA4.3_16	The IQS should integrate a Business Management Tool
T1.2_KTA4.3_17	The IQS should integrate a Health & Safety Management Tool
T1.2_KTA4.3_18	The IQS should integrate an Environmental Management Tool
T1.2_KTA4.3_19	The IQS should integrate a Social Acceptance Management Tool
T1.2_KTA4.3_20	The IQS should integrate a Sustainable Quarrying information management Tool
T1.2_KTA4.3_25	One data lake per quarry site must be deployed ensuring a sustainable over time and scalable data model platform
T1.2_KTA4.3_26	The data lake must allow the storage of structured and unstructured data at any scale coming from different heterogenous sources in the quarry site including the sensors and expert systems in a single data platform
T1.2_KTA4.3_27	The Data lake must be accessible 24h
T1.2_KTA4.3_28	The Data lake should be fulfilled with data in real time and by batch
T1.2_KTA4.3_29	The Data lake must allow data history storage (a long-term storage, purge and archiving)
T1.2_KTA4.3_32	A data lake should provide processing capabilities in batch or stream-processing mode for data analysis
T1.2_KTA4.3_34	The data lake should provide an access to the central data warehouse to achieve AI activities on request (activities/access)
T1.2_KTA4.3_35	The data lake should provide data *in a timely fashion being on an instantaneously, hourly, daily, and any other frequency basis*
T1.2_KTA4.3_36	The data lake should provide access to the schedules (planned tasks), BIM models
T1.2_KTA4.3_38	The IQS should be compliant with GDPR rules
T1.2_KTA4.3_41	The IQS should be functional. All the sub-components shall be integrated and deployed and ready to be used for quarrying operations in the pilot sites. *It is reminded that the following milestones have been agreed:* ▪ *Prototypes/ first versions from WPs 2, 3, 5 integrated in a first version of IQS for pilot implementation in M31 (MS8)* ▪ *Upgraded versions from WPs 2, 3, 5 integrated in an upgraded IQS version already installed in the pilots in M37 (MS9)* ▪ *IQS validated at pilot sites M46 (MS10)*
Non-functional requirements	
T1.2_KTA4.3_3	The IQS should be deployed as SaaS
T1.2_KTA4.3_4	The IQS should make usage of mature Open Source frameworks in order to provide sustainable solutions and ease of maintenance
T1.2_KTA4.3_5	The IQS should integrate the expert systems (sub-platforms) through generic interfaces. *Interfaces to be defined in T4.1 and implemented in T4.2*
T1.2_KTA4.3_6	Several connectors should be developed by data providers (expert systems, BIM, AI, ...) to enable the integration with the IQ
T1.2_KTA4.3_21	The IQS should deploy an IoT Platform depending on partners' needs.

ID Requirements	Requirements descriptions
	An IoT platform interconnects things based on existing and evolving information and communication technologies. It constructs an IoT eco-system of objects of the physical world. The IoT platform allows the digital representation of the devices on the quarry field. For that, it will gather data from the sensors and the expert systems. The IoT platform also allows the development of applications using data from IoT data sources. These applications will cover all the mining processes: Blasting, Drilling, Loading & Transport, Storage, Treatment and Transport. The created applications will enable services that support the smart, sustainable and digital quarry. E.g., H&S, Efficiency, selectivity & profitability, Environmental Impact, Social Acceptance, Autonomous/remote operations, Process control, Advanced analytics, etc. Data will be provided through Rest APIs. The IoT platform will provide access to IoT data
T1.2_KTA4.3_22	The IoT objects providers should manage IoT objects/data models. *Each data provider will have to create specific tools to acquire and send data according the interfaces defined in T4.2*
T1.2_KTA4.3_23	An IoT platform should be setup and configured according to Quarries' needs on the basis of the chosen IoT components
T1.2_KTA4.3_24	The expert systems (sub-platforms) should develop the connectors that enable the interaction with the IoT platform through publish/subscribe procedures.
T1.2_KTA4.3_30	Adequate communication interface with data/sensors providers shall be used to store efficiently sensors data in the data lake
T1.2_KTA4.3_31	The data lake should enable the storage in any of the following: cloud file system, SQL and NoSQL database
T1.2_KTA4.3_33	The data lake should allow the using of different tools like multiple big data frameworks like Spark, Spark-streaming, Hadoop, Kafka, RabbitMQ, Nifi (list to be validated in task 4.1)
T1.2_KTA4.3_37	Several connectors should be developed by data providers to enable the integration with the BIM and extract data from data lake. The IQS should allow the synchronisation with the schedules and BIM models.
Transition requirement	
T1.2_KTA4.3_39	IQS provider/integrator should provide support to the pilot sites regarding the deployed ICT tools in order to: ▪ keep the IQS functional ▪ maintain operational the data flow between the systems ▪ solve any technical malfunction of the ICT tools ▪ perform some refinements of the ICT tools if necessary ▪ ensure the follow-up on the ICT-related issues reported by the pilot sites during operations
Project requirement	
T1.2_KTA4.3_40	A benchmark should be performed to select the best digitalisation tools ▪ Data lake ▪ Iot Platform elements ▪ date warehouse by considering the state of the art, defining evaluation criteria and identifying potential solutions. Open-Source solutions will be prioritised

5.3.2 Use cases description related to KTA 4.3

The latter requirements are covered by the following use cases described by actor in the next sub-sections.
The diagram below presents the main identified actors of the System: those who act directly on the System, those who trigger events.

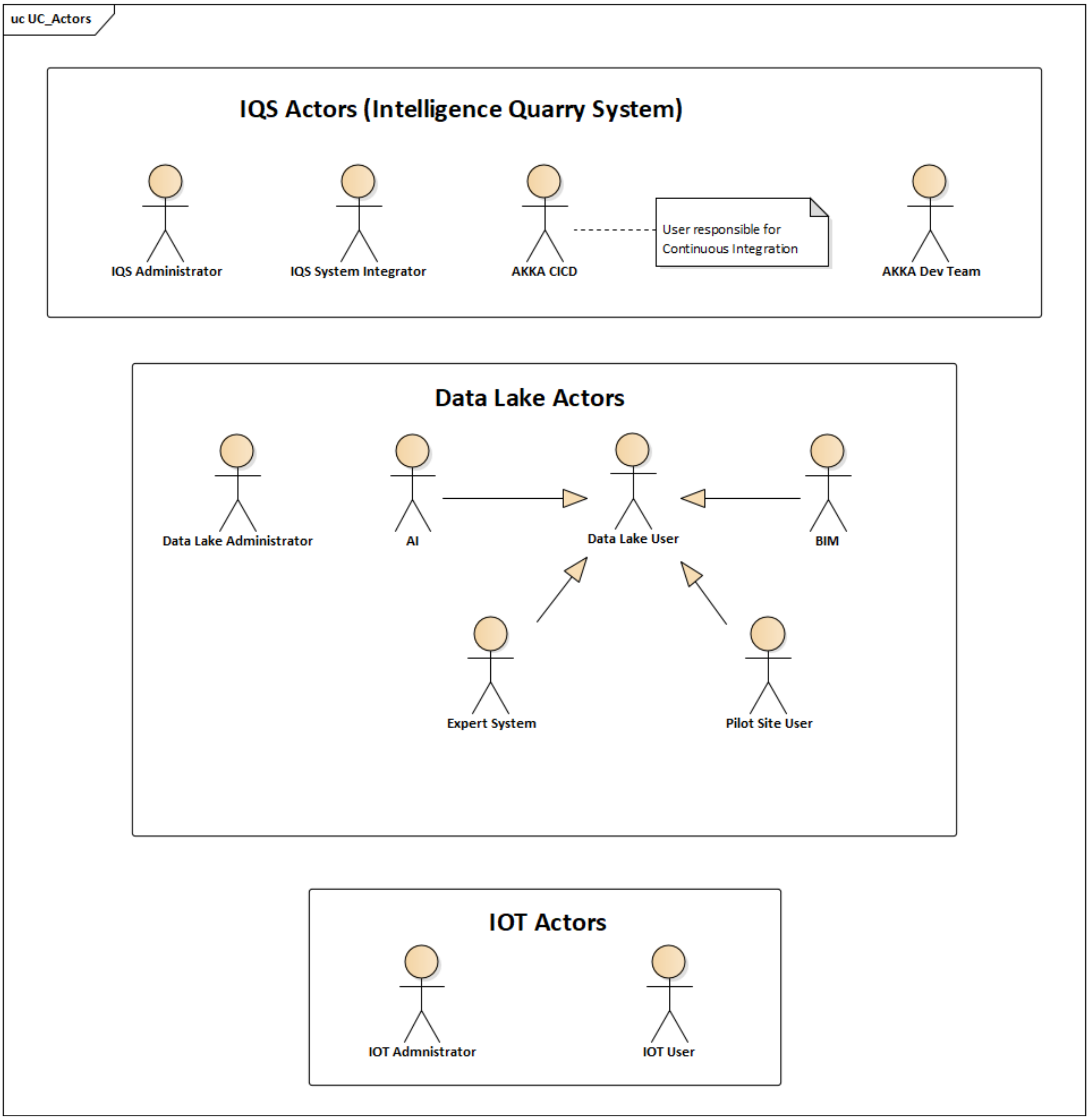


Figure 17: IQS, Data Lake and IoT actors

5.3.2.1 Global integration and IQS

Regarding the **global integration and the IQS**, here are the **use cases descriptions**.

The diagram below presents the features that the role IQS Admnistrator uses.

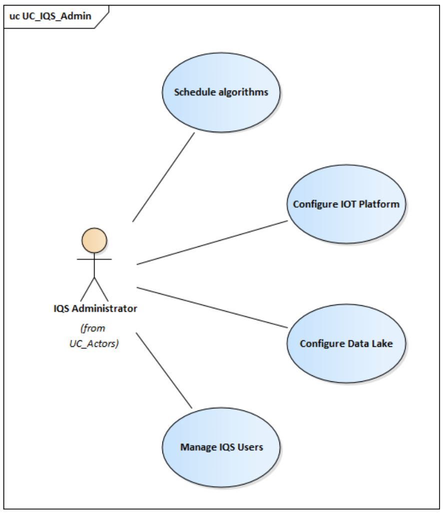


Figure 18: Use cases dedicated to the IQS Administrator role

The diagram below presents the features that the role IQS System Integrator uses.

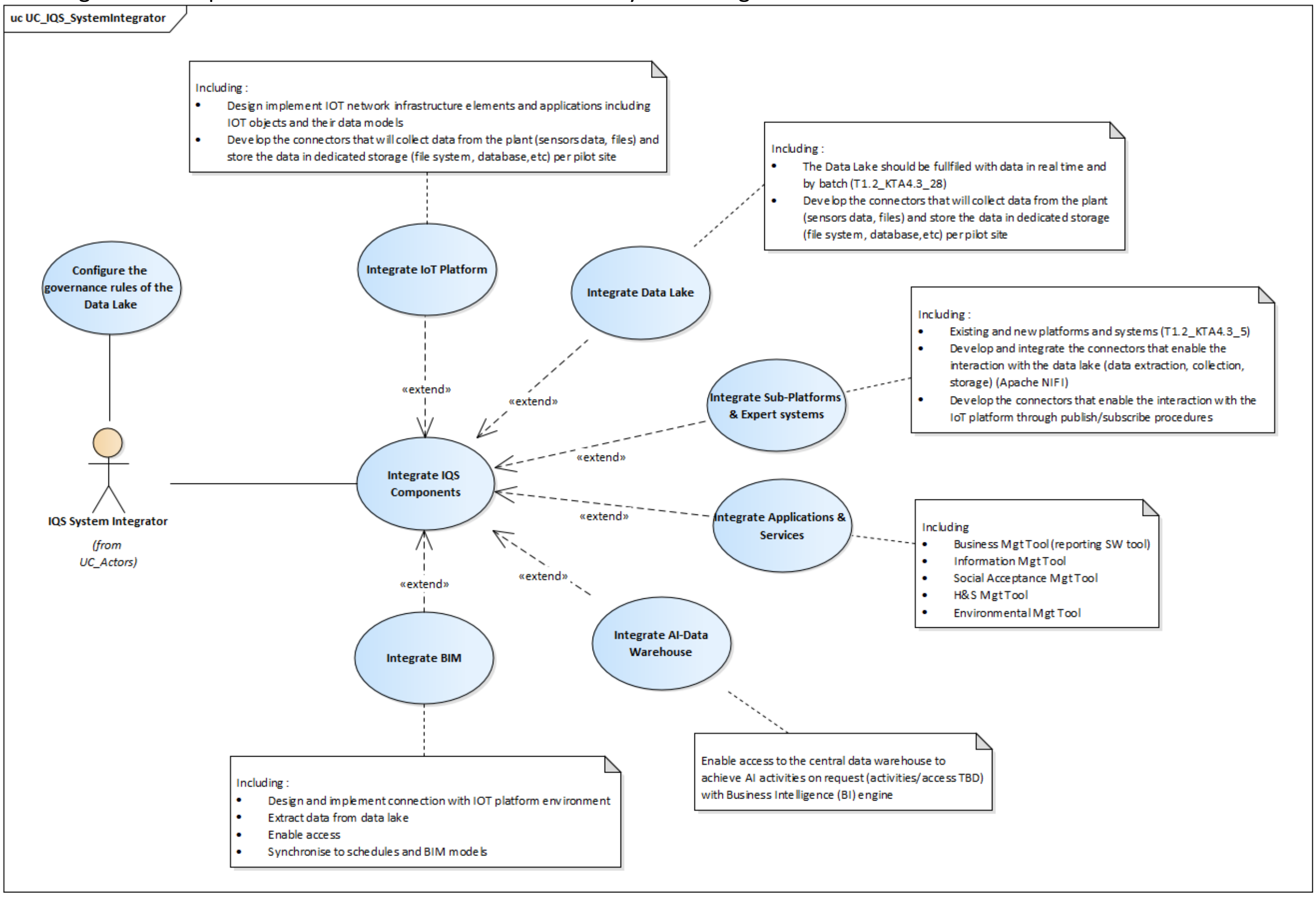


Figure 19: Use cases dedicated to the IQS System Integrator role.

The diagram below presents the features that the role AKKA CICD (Continuous Integration / Continuous Distribution) uses.

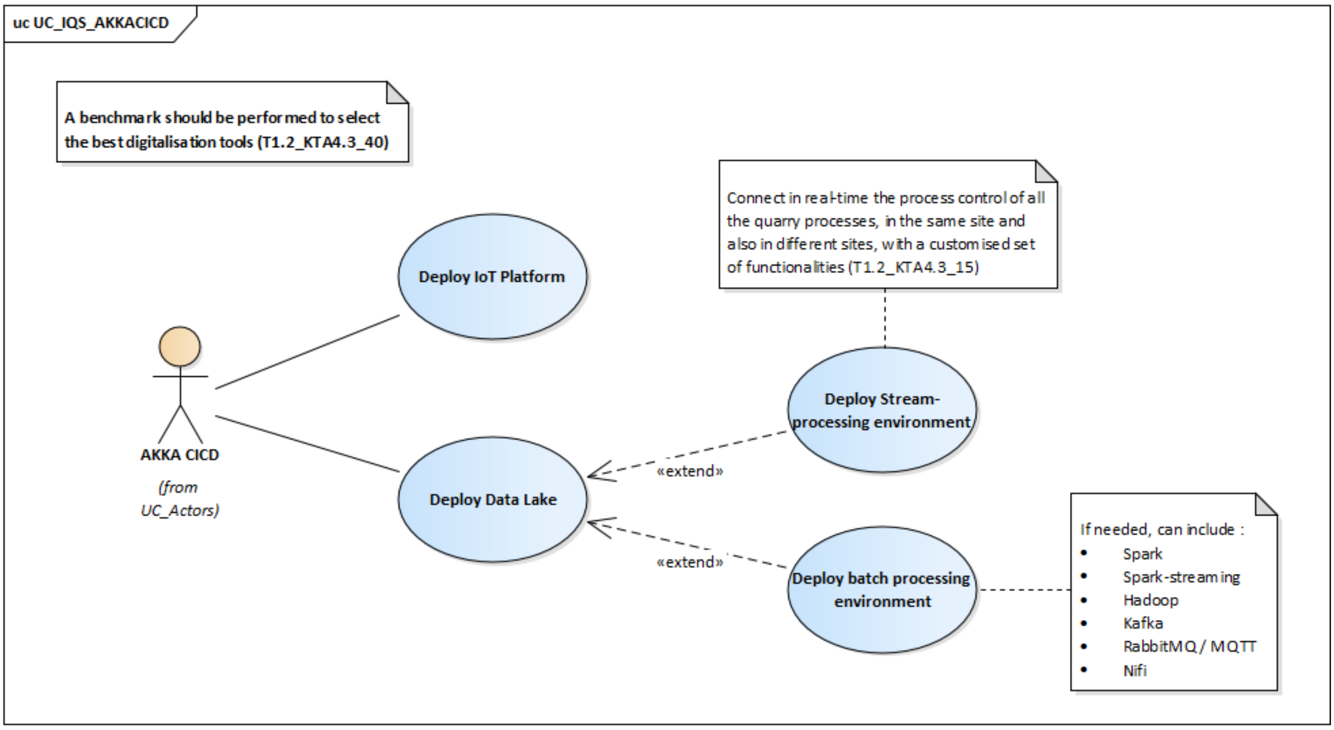


Figure 20: Use cases dedicated to the AKKA CICD role.

The diagram below presents the features that the role AKKA Development Team uses.

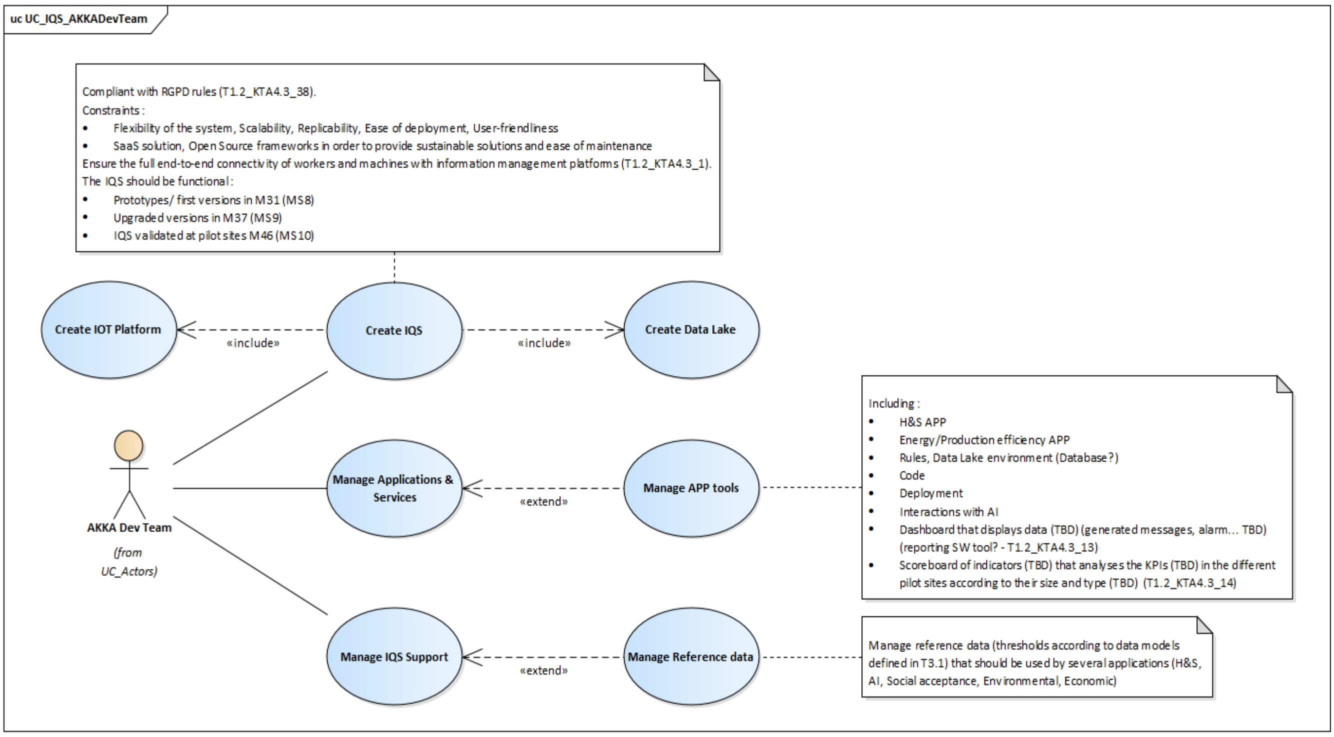


Figure 21: Use cases dedicated to the AKKA development team role.

Table 17: List of the use cases for the global integration and the IQS

Use case ID	Use case name	Use case description and steps
T1.2_KTA4.3_UC1	Create IQS	As AKKA Dev Team I want to Create IQS in order to set up the main functionalities & architecture of the platform in accordance with the main requirements identified. *Step 1* Connection to solution provider (azure, aws…) *Step 2* Domain name creation (DNS configuration, https certificate...) *Step 3* Server configuration: scalability, replicability, data redundancy… *Step 4* Local legislation rules: GDPR… *Step 5* Access right and role definitions *Step 6* Create all components defined in the benchmark to be performed in task 4.1 (IoT platform, data lake, user management…)
T1.2_KTA4.3_UC2	Integrate the IQS components	As an IQS System integrator I want to Integrate IQS Components in order to create an IQS. *Step 1* Connection to the IQS *Step 2* In accordance with the pilot site's requirements integrate only components required. *Step 3* Integrate Data Lake with its connector. (UC26) *Step 4* Integrate IoT platform with its connector (UC27) *Step 5* Integrate Sub Platform & Expert systems with its connector (UC25) *Step 6* Integrate BIM with its connector (UC22) *Step 7* Integrate AI & Datawarehouse with its connector (UC23) *Step 8* Integrate App & Services with its connector (UC24)
T1.2_KTA4.3_UC3	Integrate BIM	As an IQS System integrator I want to Integrate BIM in order to connect it with the IQS. *Step 1* IQS System Integrator connect to IQS and its management platform. *Step 2* IQS System Integrator configures access rights for the BIM to the Data Lake *Step 3* IQS System Integrator integrates the BIM connector to the IQS. Enabling access to the IoT platform and the data lake features. The integration will be performed for each quarry that will request the BIM
T1.2_KTA4.3_UC4	Integrate AI - Data Warehouse	As an IQS System integrator I want to integrate AI components and Data warehouse in order to connect them with the IQS
T1.2_KTA4.3_UC5	Integrate Applications & Services	As an IQS System integrator I want to Integrate Applications & Services in order to provides access to data with open sources tools like Business Managements, reporting, H&S…. *Step 1* IQS System Integrator deploys the App & services connectors that enable the data communication with Data Lake and IoT Platform. *Step 2* IQS System Integrator configures access rights for the App & services to the Data Lake *Step 3* IQS System Integrator configures access rights for the App & services to the IoT Platform *Step 4* IQS System Integrator deploys the App & services connectors that enable the data communication with the quarry AI models which are deployed in the central data warehouse AI system.

Use case ID	Use case name	Use case description and steps
		Step 5 IQS System Integrator configures access rights for the App & services to the quarry AI models which are deployed in the central data warehouse AI system or in the IQS. *Step 6* IQS System Integrator configures access rights for the App & services to Business Management Tool. *Step 7* IQS System Integrator deploys the App & services connectors that enable the data communication with Business Management Tool.
T1.2_KTA4.3_UC6	Integrate Sub-Platforms & Expert Systems	As an IQS System integrator I want to Integrate Sub-Platforms & Expert Systems to enable bidirectional access to data shared within the data lake. *Step 1* IQS System Integrator configures access rights for the Sub-Platforms & Expert Systems to the IoT Platform *Step 2* IQS System Integrator configures access rights for the Sub-Platforms & Expert Systems to the Data Lake *Step 3* IQS System Integrator deploys the Sub-Platforms & Expert systems connectors that enable the data communication with IoT Platform. *Step 4* IQS System Integrator deploys the Sub-Platforms & Expert systems connectors that enable the data communication with Data Lake.
T1.2_KTA4.3_UC7	Integrate Data Lake	As an IQS System integrator I want to Integrate Data Lake in order to store data from different source and format. *Step 1* IQS System Integrator connects to the datalake provider platform. *Step 2* IQS System Integrator creates the Data Lake *Step 3* IQS System Integrator configures access rights for the plant to the Data Lake *Step 4* IQS System Integrator integrates the plant connector to the Data Lake *Step 5* IQS System Integrator configures access rights for Batches to the Data Lake
T1.2_KTA4.3_UC8	Integrate IoT Platform	As an IQS System integrator I want to Integrate IoT Platform in order to exchange data form different source and format. *Step 1* IQS System Integrator connects to the IoT Platform provider platform. *Step 2* IQS System Integrator creates the IoT Platform *Step 3* IQS System Integrator design implement IoT network infrastructure elements and applications including IoT objects and their data models. *Step 4* IQS System Integrator configures access rights for the plant to the IoT Platform *Step 5* IQS System Integrator integrates the plant (IoT devices, sensors, expert systems) connector to the IoT Platform *Step 6* IQS System Integrator configures access rights for the IoT Platform to the Data Lake *Step 7* IQS System Integrator integrates the IoT Platform connector to the Data Lake
T1.2_KTA4.3_UC9	Deploy IoT Platform	The deployed components will depend on:

Use case ID	Use case name	Use case description and steps
T1.2_KTA4.3_UC10	Deploy Data Lake	▪ the benchmark results. ▪ the integration results with the external systems (expert systems) ▪ the non-functional constraints of expert systems
T1.2_KTA4.3_UC11	Deploy batch processing environment	
T1.2_KTA4.3_UC12	Deploy Stream-processing environment	
T1.2_KTA4.3_UC13	Manage IQS Applications	As an AKKA Dev Team member, I must embed into IQS Platform (Data Lake Platform and IoT Platform), the applications developed by Partners or by AKKA that will run over the IQS Platform. The involved Partners can be Expert Systems, AI, BIM. The applications could be algorithms, ML, reports, databases, any applications or code with interest to compute intermediate data or to deliver final Indicators (KPI) used by Business Management Tools. That includes: ▪ Health and Safety applications ▪ Energy and Production Efficiency applications ▪ Data Dashboards ▪ KPI Scoreboards Note that a part of these implementations could be the same for all the Pilot Sites (for KPI, pipelines, etc. common to all Pilot Sites), but some parts could be different (for KPI, algorithms, etc. dedicated to a particular Pilot Site)

T1.2_KTA4.3_UC14	Manage IQS Support	As an IQS administrator (AKKA) I want to manage IQS support in order to:
		▪ Support DigiEcoQuarry partners:
		  o provide a continuous support to the pilot sites regarding the deployed ICT tools.
		  o keep the IQS functional.
		  o maintain the data flow between the systems.
		  o solve any technical malfunction of the ICT tools.
		  o ensure the follow-up on the ICT-related issues reported by the pilot sites during operations.
		  o perform some refinements of the ICT tools if necessary.
		▪ Manage IoT subscriptions (notify external actors when data is added, alert/warn actors when thresholds are reached, or triggers occur...) (refer to UC24)
		▪ Define data retention policies (long-term storage, purge and archiving) (refer to UC15)
		▪ Manage reference data (thresholds value according to data models that should be used by several application: H&S, AI, Social acceptance, Environmental, Economic) (refer to UC16)

T1.2_KTA4.3_UC15	Define data retention policies	As a Data Lake administrator, I want to define data retention policies of my data lake in order to retain relevant information for operational future uses or references of the quarry. *Step 1* The Data Lake administrator selects a data type. *Step 2* The Data Lake administrator defines the data retention time
T1.2_KTA4.3_UC16	Manage Reference data	As an AKKA dev Team member I want to manage reference data within the data lake to use them during data processing *Step 1* The user connects to the system.

Use case ID	Use case name	Use case description and steps
		Step 2 The user performs one of the following data reference: Create, Update, Read or Delete one reference data
T1.2_KTA4.3_UC17	Configure the governance rules of the Data Lake	As a System Integrator, I must configure the Data Lake in terms of technical parameters: ▪ Performance (Standard, Premium) ▪ Replication (Data Backup, Zone Redundancy, DataCenter) ▪ Data Protection (Recovery, Tracking) ▪ Permissions (Restrictions) ▪ Certificates (Secured Access) This parametrization must be done for each created Data Lake
T1.2_KTA4.3_UC18	Authenticate & Authorize	As a Data Lake or IoT user (e.g.: AI, Expert System, Pilot site user, BIM, Device IoT), I want to access my Data Lake and IoT environments in order to manage their data. <u>For a user:</u> *Step 1* The user enters its login/password in the Data Lake or IoT environment authentication page. *Step 2* The system authenticates the user. *Step 3* The system authorizes the user to perform the requested operation <u>For a device:</u> *Step 1* The device authenticates itself with a key. *Step 2* The system authenticates the device. *Step 3* The system authorizes the device to perform the requested operation

5.3.2.2 Data Lake

Regarding the **data lake**, here are the **use cases descriptions.**

The diagram below presents the features that the role Data Lake Admnistrator uses.

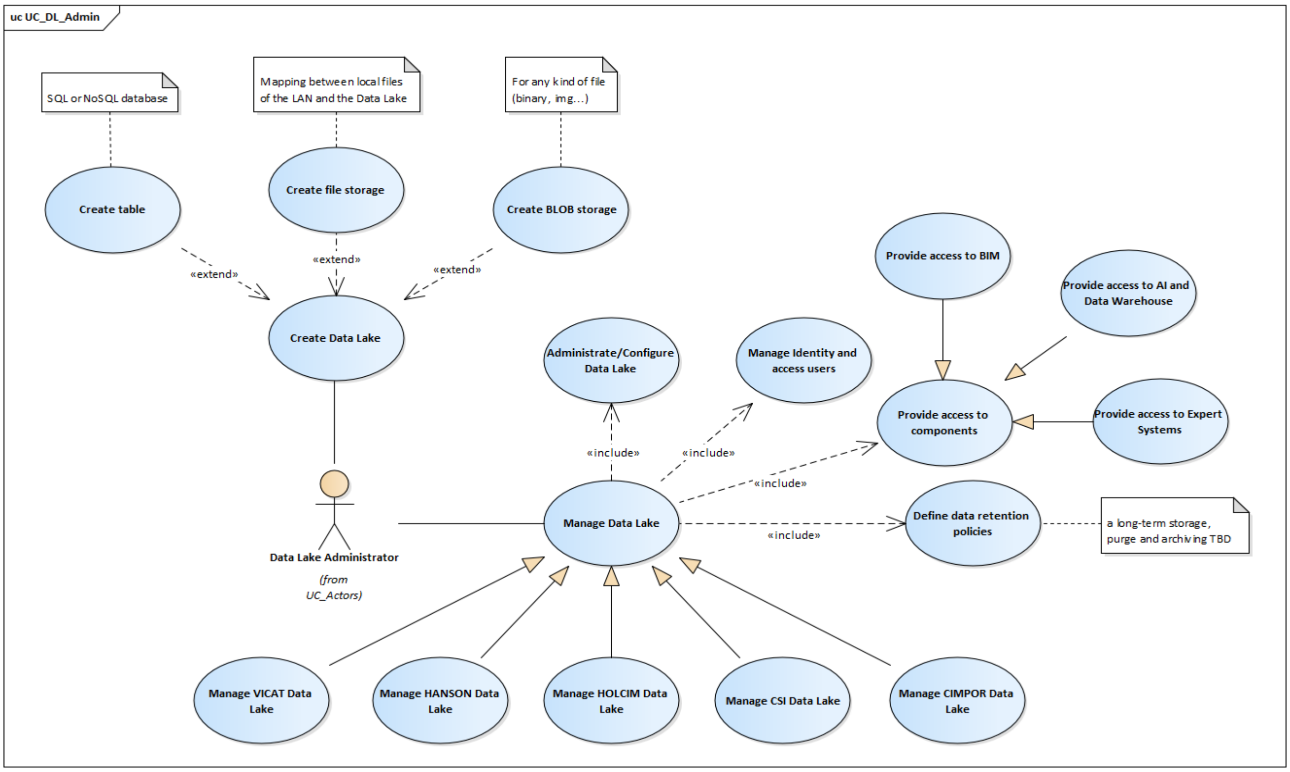


Figure 22: Use cases dedicated to the data lake administrator role

The diagram below presents the features that the role Data Lake User uses.

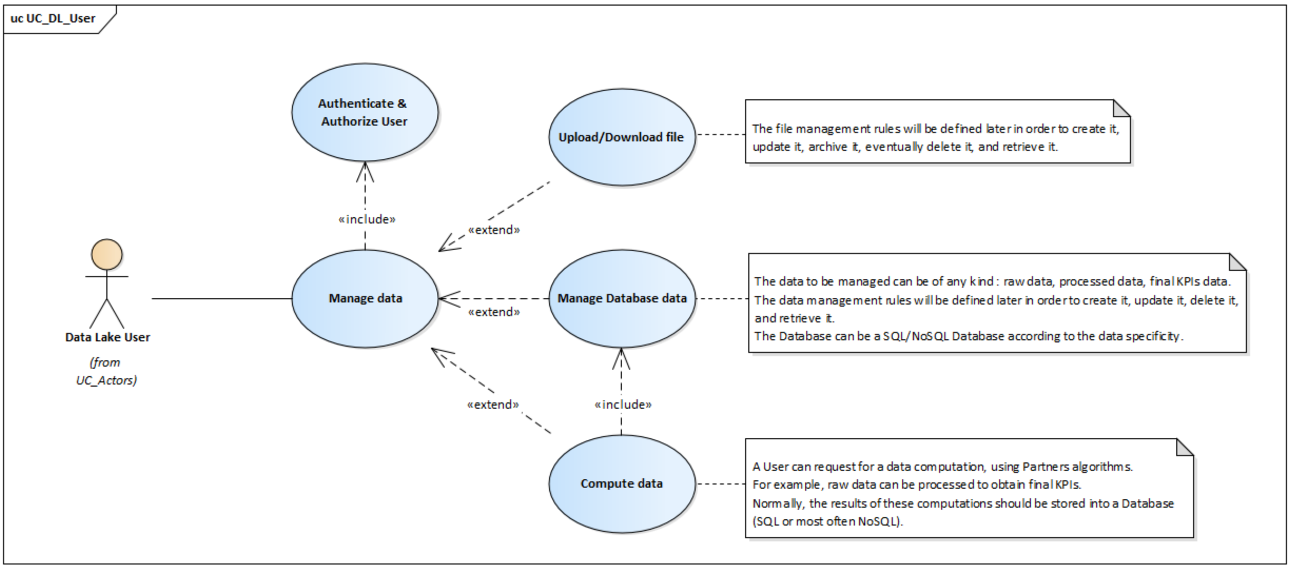


Figure 23: Use cases dedicated to the data lake user role.

Use cases description:

Table 18: List of the use cases for the Data Lake

Use case ID	Use case name	Use case description and steps
T1.2_KTA4.3_UC19	Create Data Lake	As a Data Lake administrator I want to create a Data Lake in order to process my data later to run different types of analytics and big data

Use case ID	Use case name	Use case description and steps
		processing for data visualization, for machine learning for better-guided decisions. Create data lake means to create all the storage of the current data lake.
T1.2_KTA4.3_UC20	Manage Data Lake	As a Data Lake administrator, I want to manage my Data Lake environment, in order to allow my Data Lake users to manage their own data. The possible functions of data lake management are: ▪ Administrate/Configure the Data Lake ▪ Manage the user's authentication and authorization to the data lake ▪ Provide access to BIM ▪ Provide access to AI/DWH ▪ Provide access to expert Systems ▪ Define data retention policies *Step 1* The Data Lake administrator connects to the Data Lake provider site *Step 2* The Data Lake administrator selects the data lake management function he/she wants to launch, among the available functions for all sites ▪ Administrate the Data Lake ▪ Manage the access authorizations to the data lake ▪ Enable access to BIM ▪ Enable access to AI/DWH ▪ Enable access to expert systems *Step 3* The Data Lake administrator defines the data retention policies (Refer to UC 15)
T1.2_KTA4.3_UC21	Manage data	As a Data Lake user I want to manage my data in order to get the relevant information and perform my daily quarry processes. Different types of data exist: file, database, events. The possible functions of the data management are: ▪ Create data ▪ Read data ▪ Update data ▪ Delete, Archive data ▪ Browse Data Lake (search/filter) These features will enable data sharing of any kind of data (Images, Files, BIM data models, etc). *Step 1* The Data Lake user connects to its predefined data lake. *Step 2* The Data Lake user performs one of the following actions according to the user's authorizations: ▪ Create data ▪ Read data ▪ Update data ▪ Delete data ▪ Browse Data Lake (search/filter) *Step 3* If possible by the selected architecture, the system sends a notification to relevant other actors who requested to be notified on files changes (add/update)

5.3.2.3 IoT Platform

Regarding the **IoT Platform**, here are the **use cases descriptions**.

The diagram below presents the features that the role IoT Admnistrator uses.

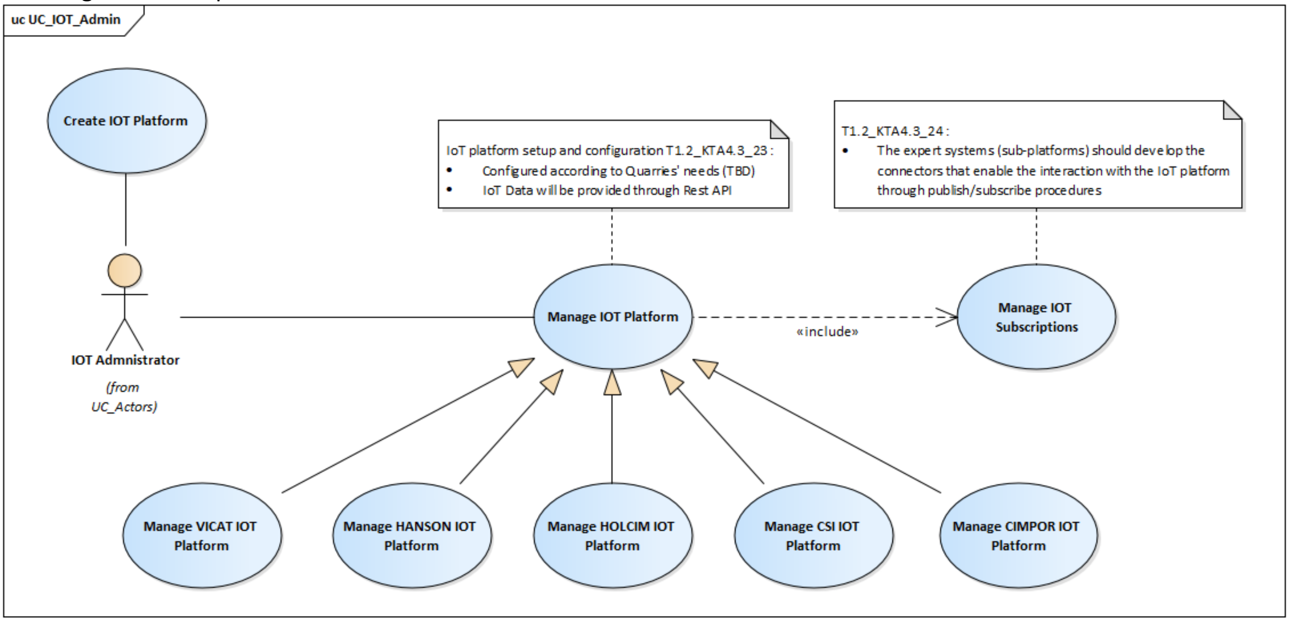


Figure 24: Use cases dedicated to the IoT Administrator role

The diagram below presents the features that the role IoT user uses.

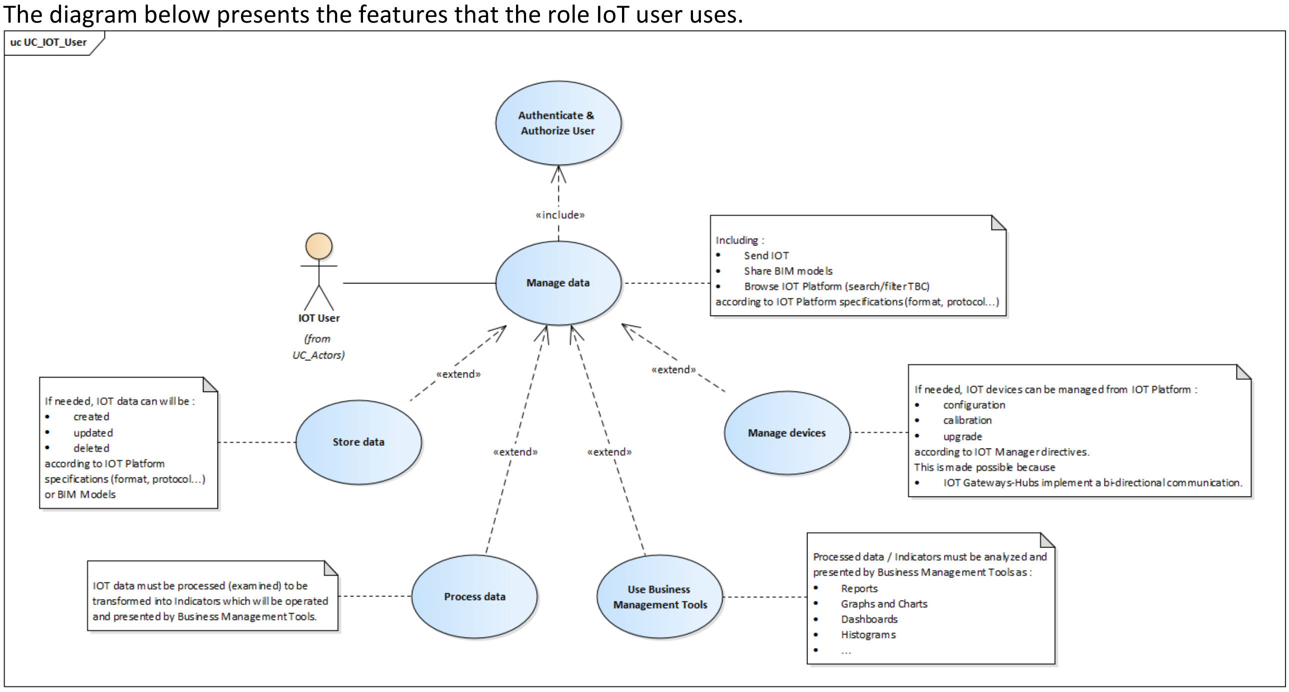


Figure 25: Use cases dedicated to the IoT user role

Use cases description:

Table 19: List of the use cases for IoT Platform

Use case ID	Use case name	Use case description and steps
T1.2_KTA4.3_UC22	Create IoT Platform	As an IoT administrator I want to create an IoT Platform in order to receive data or events from my on-site devices (sensors, camera…) that are used to generate insights, which are used to generate actions to help improve my business or my processes.

Use case ID	Use case name	Use case description and steps
		Following IoT Core subsystems and main principles depicted in Figure 31, the created IoT platform will provide: ▪ a Secured IoT Gateway ▪ an Event Manager that dispatches the tasks to be done over Pipelines and Workflows ▪ appropriate computing tasks to manage incoming data or already ingested data: ▪ hot computing for data that must be treated at real-time ▪ warm computing for data that can be treated for longer intervals (>= 5-10 minutes) ▪ cold computing for data ingested a while ago, that are not in the critical path (once an hour, once a day) ▪ a BI Platform that produces insights, synthesis, smart views as reports, charts, histograms, dashboards, scoreboards, etc. During the IoT Platform Creation, these components must be parametrized and customized.
T1.2_KTA4.3_UC23	Manage IoT Platform	As an IoT administrator I want to Manage IoT Platform in order to allow my users to manage their own data. The possible functions of IoT platform management are: ▪ Administrate/Configure the IoT platform, ▪ Manage the user's authentication and authorization to the IoT platform ▪ Provide access to BIM ▪ Provide access to AI/DWH ▪ Provide access to expert systems ▪ Manage devices *Step 1* The IoT platform administrator connects to the IoT platform provider site. *Step 2* The IoT platform administrator selects the IoT platform management function he/she wants to launch, among the available functions. ▪ Administrate the IoT platform ▪ Manage the access rights/permission to the IoT platform ▪ Provide access to BIM ▪ Provide access to AI/DWH ▪ Provide access to expert systems ▪ Manage devices- Provide access through REST APIs *Step 3* The IoT platform administrator manages the IoT platform subscriptions (Refer to UC35)
T1.2_KTA4.3_UC24	Manage IoT subscriptions	As an IoT Administrator, I want to forward IoT data to one of the following components: ▪ Data lake for storage ▪ Expert systems ▪ BIM ▪ AI, Data warehouse ▪ Applications, Business Management tools ▪ Any external system (API Rest)
T1.2_KTA4.3_UC25	Manage IoT Data	As an IoT user (e.g.: AI, Expert System, Pilot site user, BIM, Device IoT) I want to manage my IoT data in order to get the relevant information to

Use case ID	Use case name	Use case description and steps
		generate insights and actions to help improve business and processes. The possible functions of data management are: ▪ Create data ▪ Send data ▪ Read data ▪ Store data in the Data Lake Step 1 The IoT user connects to its predefined IoT platform. Step 2 The IoT user performs one of the following actions: ▪ Create data ▪ Send data ▪ Read data Step 3 The system stores IoT data in the Data Lake if needed. Step 4 The system sends a notification to relevant other actors who requested to be notified when new data is received (published)

5.4 Business management tool

The IQS business management tool aims at supplying dashboards and reports to quarry stakeholders for survey, analysis and decision support. The information is retrieved from various sources. The tool will answer the general needs:

- Take advantage of various data generated by the quarry processes, stored in data lakes, expert systems, IoT platform, AI, BIM, or entered manually
- Integrate different datasets generated by partners expert systems
- Control and improve business processes
- Consolidate data, through aggregation and filtering
- Create customable dashboards made of charts and tables, related to quarry processes monitoring or supporting decision (graphical reports)
- Consider login credentials

5.4.1 Requirements for the implementation of KTA 4.4

Table 20: List of the requirements for the global integration and the IQS

ID Requirements	Requirements descriptions
Functional requirements	
T1.2_KTA4.4_12	Annual production
T1.2_KTA4.4_26	Productivity in mobile machinery
T1.2_KTA4.4_27	Time used for non-productive work
T1.2_KTA4.4_28	Productivity in drilling - savings in sizing costs
T1.2_KTA4.4_29	Productivity in drilling - production increase
T1.2_KTA4.4_30	Fragmentation size and homogeneity
T1.2_KTA4.4_31	Blast quality
T1.2_KTA4.4_32	Quality control
T1.2_KTA4.4_37	Energy Consumption
T1.2_KTA4.4_39	Fuel consumption
T1.2_KTA4.4_40	Energy intake

ID Requirements	Requirements descriptions
T1.2_KTA4.4_55	Energy consumption in comminution processes
T1.2_KTA4.4_56	Productivity in drilling -fuel consumption
T1.2_KTA4.4_92	Analysis by slots
T1.2_KTA4.4_93	Hobbs meter
T1.2_KTA4.4_94	Fuel consumption - Subcontractor
T1.2_KTA4.4_96	Loading time - Machinery
T1.2_KTA4.4_97	Transport times - Machinery
T1.2_KTA4.4_98	Assign materials to stockpiles
T1.2_KTA4.4_100	Corrective maintenance Mobile machinery €/t
T1.2_KTA4.4_101	Volumetric control of stockpiles per product
T1.2_KTA4.4_102	corrective maintenance Fixed machinery €/t
T1.2_KTA4.4_104	Preventative maintenance Mobile machinery €/t
T1.2_KTA4.4_106	preventative maintenance Fixed machinery €/t
T1.2_KTA4.4_108	scheduled maintenance Mobile machinery €/t
T1.2_KTA4.4_109	Flow measurement (general and by product)
T1.2_KTA4.4_110	scheduled maintenance Fixed machinery €/t
T1.2_KTA4.4_114	t/h (production) vs. the maximum t/h the plant capacity (or is designed)
T1.2_KTA4.4_115	Machine downtime
T1.2_KTA4.4_116	Hours or number of times the plant has started late or stopped before the scheduled time
T1.2_KTA4.4_122	t/h per employee
T1.2_KTA4.4_123	total working hours
T1.2_KTA4.4_124	operating hours
T1.2_KTA4.4_125	Net availability index
T1.2_KTA4.4_126	Utilization Index
T1.2_KTA4.4_84	The IQS should allow the integration of a Reporting SW tool which will address: ▪ the H&S impacts and related KPIs ▪ the Environmental impacts and related KPIs ▪ the Social impacts and related KPIs ▪ the Economic impacts and related KPIs
T1.2_KTA4.4_85	All the data processed within the IQS should enable KPI monitoring
Transition requirement	
T1.2_KTA4.4_129	QA/QC linked to individual technical product specifications
Project requirements	
T1.2_KTA4.4_88	Compare KPIs with a target or a user-defined history (last year, last 6-3 months...)
T1.2_KTA4.4_90	Deploy a business scoreboard essential
T1.2_KTA4.4_91	Evolution over time of the KPI (user-defined)
T1.2_KTA4.4_105	Production forecasting
T1.2_KTA4.4_118	Asset availability filtering by time
T1.2_KTA4.4_119	Primary rejection (from blasting)
T1.2_KTA4.4_120	t or % of fines - reject
T1.2_KTA4.4_127	Production Rate Index
Business requirements	
T1.2_KTA4.4_11	Cost reduction
T1.2_KTA4.4_13	Annual net sales
T1.2_KTA4.4_16	Investment in geological and mining research & management
T1.2_KTA4.4_17	Capital expenditures
T1.2_KTA4.4_18	Internal Rate of Return
T1.2_KTA4.4_19	Incomes increase
T1.2_KTA4.4_20	Net Present Value

ID Requirements	Requirements descriptions
T1.2_KTA4.4_21	Operational expenditure
T1.2_KTA4.4_58	EXTERNAL transport distances by logistic management
T1.2_KTA4.4_59	INTERNAL transport distance by logistic management
T1.2_KTA4.4_78	Level of reporting
T1.2_KTA4.4_79	level of reporting for the extractive industry
T1.2_KTA4.4_86	Run intrasite or intersite analysis.
T1.2_KTA4.4_87	Aggregation at zone, region, country level....
T1.2_KTA4.4_89	Filtering by activity (restoration, drill and blast etc...)
T1.2_KTA4.4_95	Optimizing truckload paths and reducing operational cost
T1.2_KTA4.4_99	Entry/exit scale for weighing trucks (type of material and tonnes and/or trucks leaving)
T1.2_KTA4.4_103	Flows and relations between products
T1.2_KTA4.4_107	Target production (general and/or by type of products)
T1.2_KTA4.4_111	Report by mobile phone photo (e.g. for security issues, maintenance...)
T1.2_KTA4.4_117	Categorize equipment that has broken down (id, reason and number of times). It filtered by date or time (in the last 3,6 months....)
T1.2_KTA4.4_130	Introduction of royalties per tonne or m2 (m3) of affectation

5.4.2 Use cases description related to KTA4.4

Achieving the targets of the EIP on Raw Materials (RM), particularly in terms of innovative pilot actions on mining for innovative production of RM.

Table 21: List of the use cases for the Business Management tool

Use case ID	Use case name	Use case description and steps
T1.2_KTA4.4_UC1	Aggregated data visualization	The user can aggregate the different performance KPIs according to time or geographic situation.
T1.2_KTA4.4_UC2	Energy consumption by product	Total energy consumption in producing one tonne of specific saleable product [t/GJ (gigajoule)].
T1.2_KTA4.4_UC3	Load and transport cycles	Quantify and measure loading and transport cycles on a daily basis by truck.
T1.2_KTA4.4_UC4	Total inventory by site and forecast	Updated quarry inventory taking into account the number of products (primary and secondary), production, forecast and output of products.
T1.2_KTA4.4_UC5	Report by photography (mobile phone)	Report with a mobile phone photo (e.g. for security issues, maintenance...).
T1.2_KTA4.4_UC7	Assess productivity with integrated machine telemetry data	Productivity is a measure of the efficiency of a machine, factory or person in converting inputs into useful outputs. For which the following are taken into account (among other things): ▪ t/h (production) ▪ Machine downtime ▪ Time of switch-on and switch-off of the machines Equipment that has broken down.
T1.2_KTA4.4_UC8	Productivity UPH (Units Per Hour, employee)	Productivity as tonnes produced (total and by product) per total worker hours (employee).
T1.2_KTA4.4_UC9	Running Equipment Effectiveness (REE)	REE measures the actual performance of the aggregates processing plant considering the Net Availability index (%), the utilization Index (%) and the Production Rate Index (%). REE compares the production volume at a plant with its best demonstrated practice.

Use case ID	Use case name	Use case description and steps
T1.2_KTA4.4_UC11	Economic management	Focuses on increasing the efficiency of organizations by employing all possible business resources to increase output while decreasing unproductive activities: ▪ To optimize decision making when the firm is faced with problems or obstacles. To analyse the possible effects and implications of both short and long-term planning decisions on the revenue and profitability of the Business.
T1.2_KTA4.4_UC12	QA QC	Reports and KPI in order to ensure quality assurance. Internal and external data used to measure and ensure the quality of a product, and KPI to evaluate the performance of a part of the quarry process (i.e. explosives characterisation, blasting results control, machine data from the extraction, analyse data in the treatment process...).
T1.2_KTA4.4_UC18	Maintenance Operations	Maintenance often involves usual and unusual work, routine and non-routine tasks and it is often performed in exceptional conditions.

6 High level logical architecture design

6.1 Global IQS architecture

The definition of the specific requirements of the different actions and tools is also developed by defining and refining the global IQS model (Figure 26) and the internal architecture needed for the specific pilot sites and to guarantee the replicability and scalability of the generic technologies and solutions for their implementation in any aggregates site in EU/World.

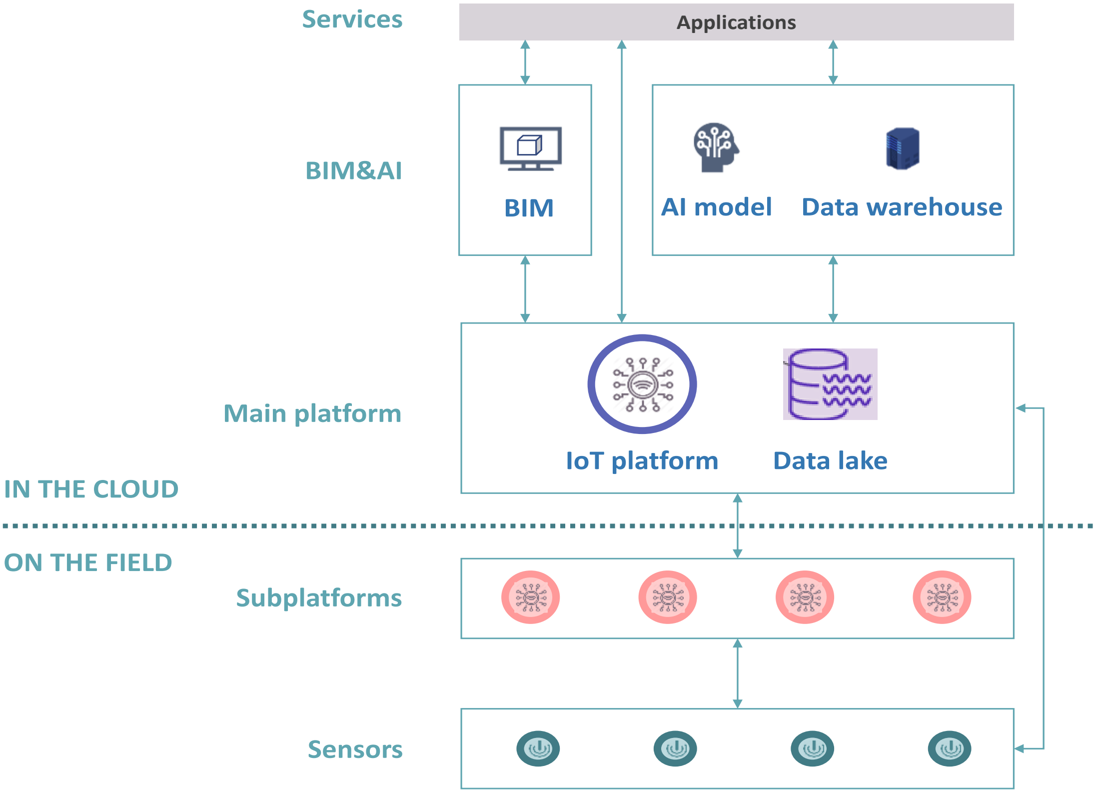


Figure 26: Global IQS architecture

Multiple interfaces will be made available to enable the communication between the data lake and the IoT platform with the following external applications and processes:

- Expert systems and sub-platforms
- BIM
- AI activities and Data warehouse
- Applications

The real-time monitoring is managed at pilot site level by dedicated expert systems:

- Real-time monitoring of fixed equipment is performed using Scada system and data can be shared (uploaded) to the Data Lake every five minutes (higher possible frequency) and aggregated per hour, per day or per month. Connectivity will be done from a PC located in the site.
- For the real-time monitoring of mobile equipments, data is collected and stored locally and uploaded to the expert system when the connection is available. Then only aggregated data are shared to the data lake on daily or monthly basis.

Note that in the frame of the WP4 of the DigiEcoQuarry project, the design of this architecture will be refined to:

- comply with the requirements which will be translated into ICT requirements in task 4.1,
- consider the functionalities and the features of the future ICT tools identified to fulfil the digitalisation needs,
- follow the benchmark recommendations.

6.2 Data lake

The Data Lake will be a centralized and secured repository, by quarry, based on the cloud, to allow, in particular, the ingestion, the storage, the analysis and the usage of relevant data, available in its native format, such as structured or unstructured files but also databases, coming from each quarry (pilot sites) as well as from the technical providers partners working with them. These cloud Data lakes will be fully administrable to enable right accesses and give appropriate permissions. Data lake users (pilot site users, BIM, AI & Data warehouse, IoT devices, expert systems), once authenticated and authorized, will be able to:

- Create, Read, Update, Delete data (download/upload), according to Data Lake specifications.
- Explore data lake content
- Share BIM, AI models and Expert system data.
- Store :
    - Files, Images (txt, xml, csv, json, zip, jpeg, xls, gis…) with associated metadata
    - Data Bases (SQL, NO SQL)

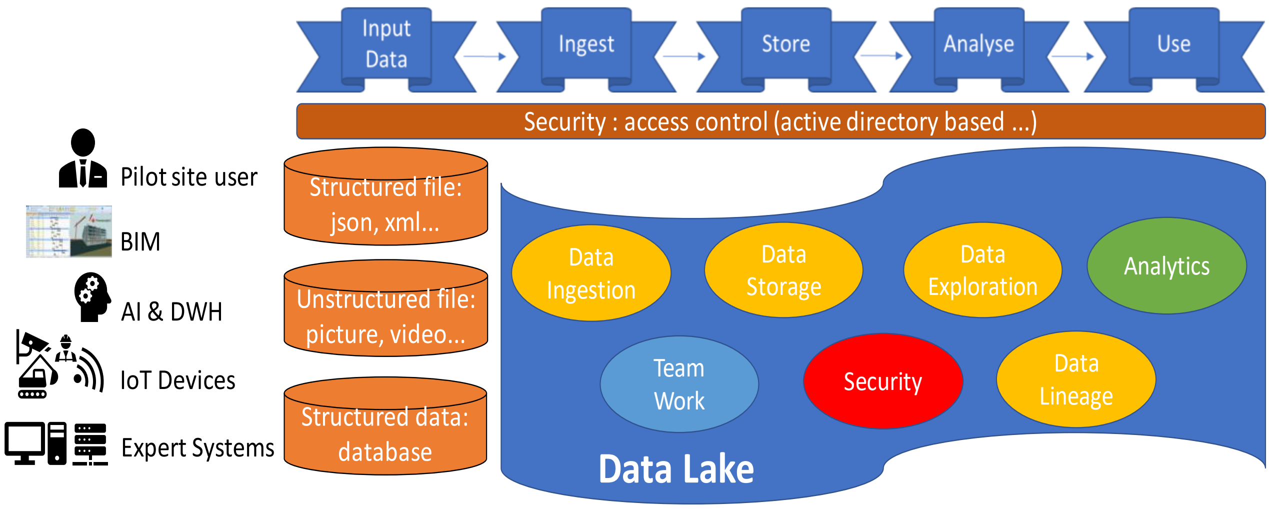


Figure 27: Data Lake global architecture

6.2.1 Components diagrams for the Data Lake

The first schema of this paragraph presents:

- the components used by any Architecture to realize a Data Lake in a Cloud (including components needed to expose the services that request and populate the Data Lake Storage)
- the communication between all these components

These components can be understood as interfaces that must be implemented in existing Cloud Architectures.

The second schema presents 3 possible implementations of the generic components of a Cloud:

- Microsoft Azure Cloud Components

- Amazon Cloud Components
- Google Cloud Components

6.2.1.1 Data Lake Generic Components Diagram

The generic components are those that any Cloud Architecture implements to make a Data Lake operable.
Please zoom up to 180 to see the diagram properly.

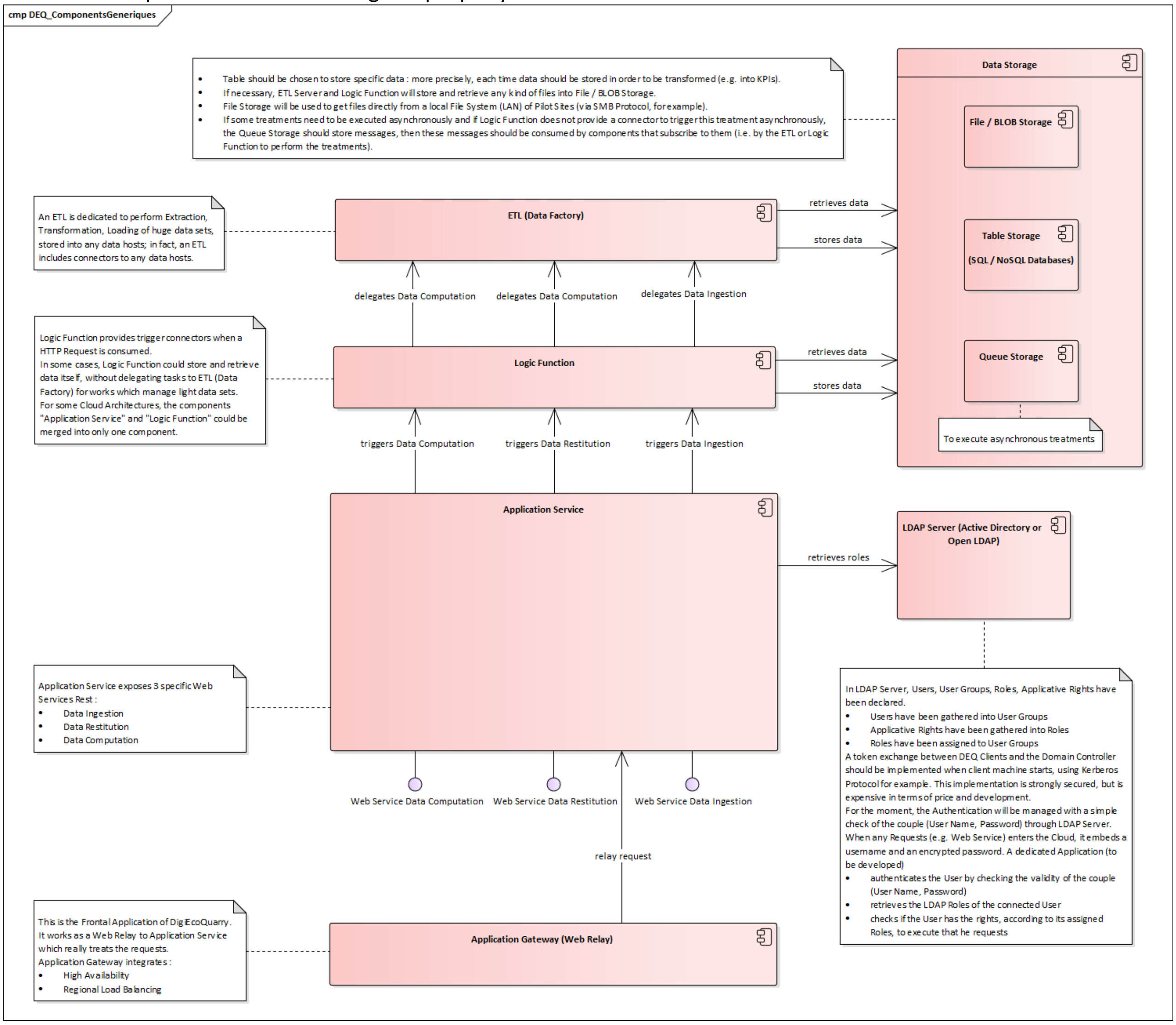


Figure 28: Data Lake generic components diagram

Table 22 : Generic Components Description for a Data Lake

Generic Components Description	
Title	**Role**
Application Gateway	An Application Gateway acts as a Web Relay at front of the Cloud. It centralizes all the requests coming from any User outside the Cloud It is a technical component that includes Load Balancing, High Availability, Communications Securization (SSL), Applications Protection (Firewall)

Generic Components Description	
Title	**Role**
Application Service	This component exposes the services offered by the application hosted in the Cloud. Usually, it exposes Web Services as a FulRest type. Functionaly, it is the front door of the applications
LDAP Server	LDAP Server contains Users information that are accessed by requesting a directory. It hosts Users authorization to all required applications. Coupled to a DNS (Domain Name System), they compose a domain controller that manages Users authentication. For a high securization, Kerberos Protocol can be added to the authentication architecture
Logic Function	After the request have been caught by the Application Service, the data treatment can start: this component triggers the treatment and orchestrates the workflow (the logic) needed to process the data. The workflow implements a sequential series of jobs and can process the treatment of each job; it behaves like an ESB (Enterprise Server Bus) by processing a high frequency of requests with a limited volume of data. However, if the treatment is heavy in terms of processing (huge data set, complex transformation…), the workflow will delegate the job treatment to a more appropriate component: the Data Factory
Data Factory: ETL Tool (Extract Transform Load)	An ETL performs a large volumetry of data. It extracts data from any incoming flow (using integrated connectors to any data storages) It treats (transforms) data using standard process or dedicated development in any languages. It loads the processed data into any storages (using integrated connectors) It must be noted that in some architectures, the Workflow Orchestrator and the Data Factory are operated by the same component
Data Storage: BLOB Storage	A BLOB Storage is dedicated to all binary files as images, videos, and so on… It can be hierarchized by "buckets" as memory storage spaces
Data Storage: File Storage	This kind of Storage is mainly used to map local directories to a remote Cloud Storage With this technology, files stored into the client LAN are automatically sent into a Cloud referential that have been configured as the mirror of the LAN (or part of LAN). In this way, files created, modified, deleted from the LAN are "immediately" created, modified, deleted into the remote File Storage Usually, the Samba Suite (Shared SMB: Server Message Block) is used to mirror the client and the remote server
Table Storage	This Storage hosts the two standard types of Databases: Relational Database and NoSQL Database
Queue Storage	It is a technical Storage which implements a publish/subscribe technology that can be used to run asynchronous treatments

6.2.1.2 Data Lake Specific Components Diagram

The following diagram shows the different Cloud Providers' components which could be used by the IQS Data Lake Architecture.
The components of the main 3 Cloud Providers are presented:

- Microsoft Azure

- Amazon Web Services
- Google Cloud Platform

All these specific components realize the generic components (exposed at the previous paragraph) considered as interfaces to be implemented.

Please zoom up to 160 to see the diagram properly.

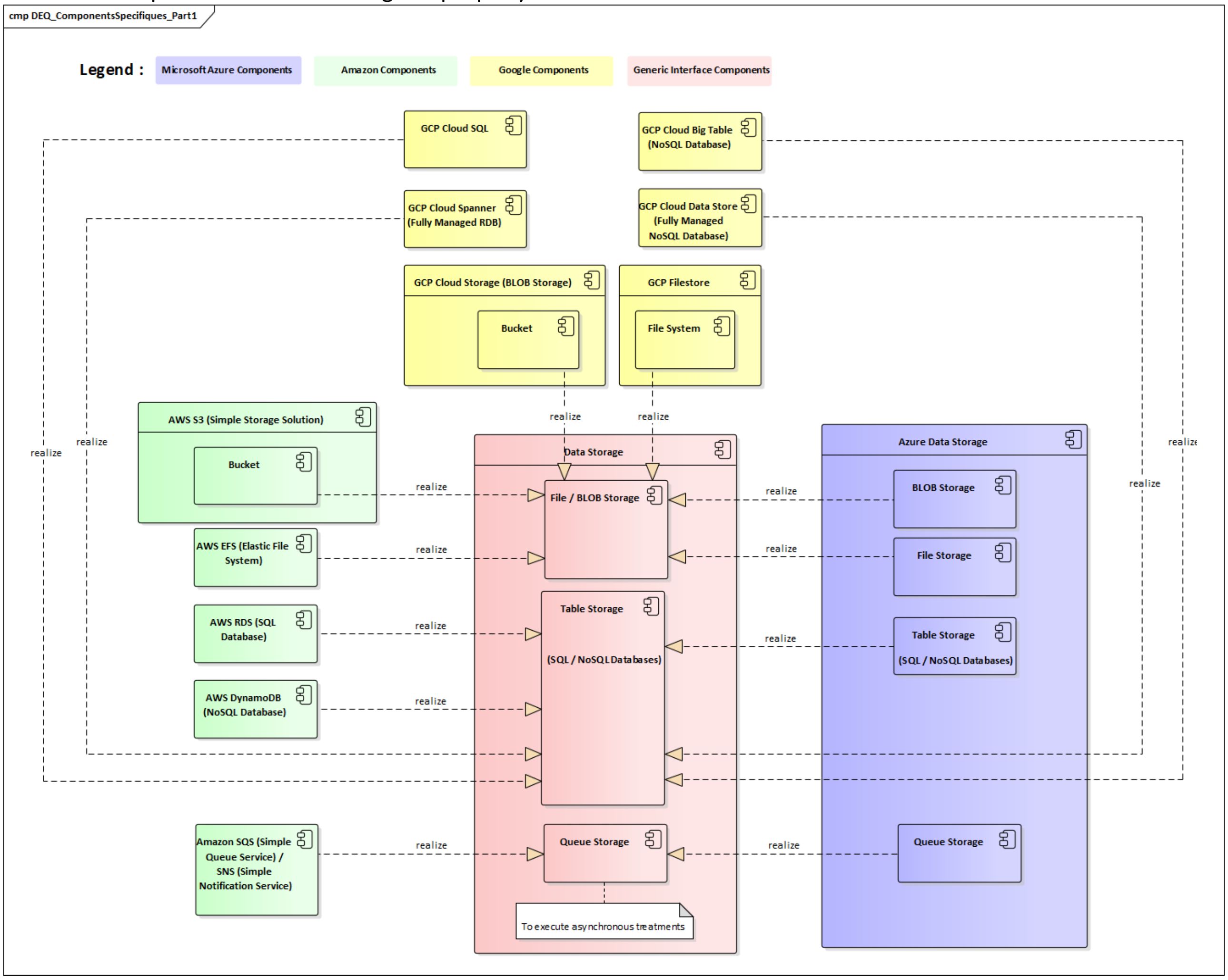


Figure 29: Data Lake specific components diagram Part1

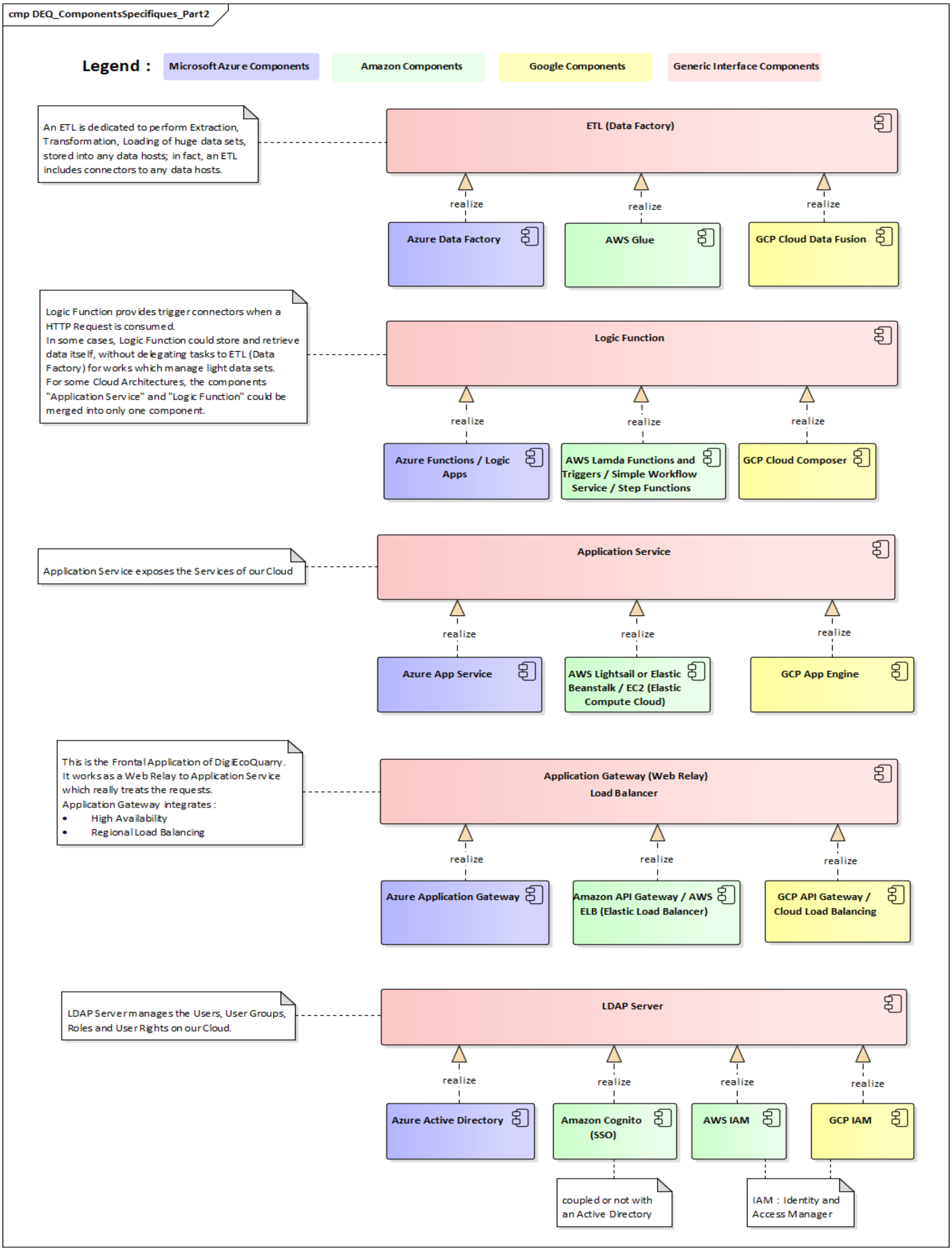


Figure 30: Data Lake specific components diagram Part2

The table below presents the specificities of the 3 Cloud components which have not been already described at the previous paragraph.

Table 23: Specific Components Description for a Data Lake

Specific Components Description	
Title	**Role**
LDAP Server – Authentication / Authorization	
Azure Active Directory	A lot of features can be added to the basic Authentication/Authorization, for example: User administration, reinforced securization, and so on… It can be noted: ▪ Azure Domain Services: DNS fully managed by Azure with Kerberos authentication. ▪ RBAC: Role Based Access Control, authorization system based on a resource manager that specifies the resources access; RBAC purposes integrated roles that can be used in the Cloud to authorize Users to native or specific resources
Amazon Cognito / IAM (Identity and Access Management)	Cognito controls User access to applications. It uses SAML (Security Assertion Markup Language) which ensures a dialog between the Service Provider and the Identity Provider, with a unique authentication by SSO. OpenIDConnect, which ensures the same features with another technology based upon OAuth 2.0, can also be used by Cognito. IAM identifies Users and provides an integrated access control to AWS resources
Google IAM	IAM manages User authentication and authorization using a role notion that gathers an authorization set and that is assigned to Users. IAM uses Google authentication based upon the standard OAuth 2.0 and can implement SAML SSO through Google Cloud Identity Platform
Application Gateway – Load Balancer	
Azure Application Gateway	It is a Load Balancer that allows routing until the Application Layer (named L7, as HTTP(S) for example): therefore, it purposes URL/URI-based routing. It integrates a suite of fully managed standard load-balancing solutions. The load balancing can make autoscaling (up/down) if needed. Application Gateway embeds the WAF service (Web Application Firewall) that protects the applications, managed by Microsoft (so always up to date) It implements the Session Affinity technology (using cookies) that allows, if needed, to "stick" (i.e., to associate) a user session to a dedicated server
AWS Elastic Load Balancer	As for Azure, ELS is a L7 Load Balancer and automatically adjusts itself to the incoming traffic (Elasticity / Autoscaling) It integrates AWS WAF (Firewall) to protect applications. It selects the load balancing algorithm to be applied according to customizable priorities. It uses Session Affinity technology to manage "sticky" sessions
Google Cloud Load Balancing	As for Azure or AWS, it is a L7 Load Balancer with autoscaling. It integrates QUIC Protocol (Quick UDP Internet Connections) created by Google. It uses Session Affinity technology to manage "sticky" sessions. It can be coupled to the Firewall service of Google VPC Network (Very Private Cloud)
Application Service	
Azure App Service	This component is a platform fully managed by Microsoft that hosts (deploys, manages, scales) Web Services
AWS Elastic Beanstalk	This component is a platform fully managed by Amazon that hosts (deploys, manages, scales) Web Services

Specific Components Description	
Title	**Role**
	Lightsail is lighter than Elastic Beanstalk and uses preconfigured and fixed Cloud resources that are not expensive (useful for a simple Proof-Of-Concept). For autoscaling and real flexibility, Elastic Beanstalk must be preferred
Google Cloud App Engine	This component is a platform fully managed by Amazon that hosts (deploys, manages, scales) Web Services
Logic Function	
Azure Logic Apps	It is an integrated platform as a service, that automatizes workflows while manages autoscaling
AWS Step Functions	It is a fully managed service that relies and orders tasks which have been described as a visual workflow
Google Cloud Composer	It is a workflow orchestrator service based upon Apache Airflow. It creates, plans and monitors graphic pipelines. It automatically scales the environment if needed
ETL (Data Factory)	
Azure Data Factory	It is the ETL factory in Azure Cloud using preconfigured connectors and transformations
AWS Glue	It is the ETL factory in Amazon Cloud using preconfigured connectors and transformations
Google Cloud Fusion	It is the ETL factory in Google Cloud using preconfigured connectors and transformations
BLOB Storage	
Azure BLOB Storage	It is designed to store unstructured data with no model definition as text, binaries, images, etc. It includes services as high availability, scalability, security
AWS S3 (Simple Storage Solution)	It is designed to store unstructured data with no model definition as text, binaries, images, etc. It includes services as high availability, scalability, security
Google Cloud Storage	It is designed to store unstructured data with no model definition as text, binaries, images, etc. It includes services as high availability, scalability, security
File Storage	
Azure File Storage	It implements a shared files System with high availability, serverless and fully managed, accessed with SMB protocol and NFS mount
AWS EFS (Elastic File System)	It implements a shared files System with high availability, serverless and fully managed, accessed with NFS mount
Google Cloud Filestore	It implements a shared files System with high availability, serverless and fully managed, accessed with SMB/CIFS protocols and NFS mount
SQL / NoSQL Database Storage	
Azure Table Storage	This functionality is available as SQL Database and NoSQL Database
AWS RDS (SQL Database)	It is the Amazon's Relational Database Service
AWS DynamoDB	It is the Amazon's NoSQL Database offer
Google Cloud SQL	This is the Google's SQL Database Service configured and managed by Customers using Google Cloud
Google Cloud Spanner	This is the Google's SQL Database Service fully-managed by Google
Google Cloud Big Table	This is the Google's NoSQL Database Service configured and managed by Customers using Google Cloud
Google Cloud Data Store	This is the Google's NoSQL Database Service fully-managed by Google
Queue Storage	
Azure Queue Storage	It is specifically used as message routing for large volume of data, for example between components of Azure Storage Queue Storage is a distributed queuing system. Messages are not pushed to receivers. Receivers must request SQS to receive messages.

Specific Components Description	
Title	**Role**
	It exists some other Azure components with pub/sub technology that allow asynchronous dialog between Azure applications; for example, Service Bus
Amazon SQS (Simple Queue Service)	Queue Storage is a distributed queuing system. Messages are not pushed to receivers. Receivers must request SQS to receive messages. It exists some other Azure components with pub/sub technology that allow asynchronous dialog between Azure applications; for example, SNS (Simple Notification Service)
Google Cloud Pub/Sub	Google only uses a main type of component to initiate an asynchronous dialog between several components: Google Publisher / Subscriber It is a fully-managed message routing service: the main component that delegates the asynchronous tasks notifies the subscriber that tasks are waiting to be treated, using Google Pub/Sub

6.2.1.3 Data Lake Alternative Components: Open Source

Table 24: Data Lake Alternative Components (Open Source)

Open-Source Components Description	
Title	**Role**
LDAP Server – Authentication / Authorization	
Open LDAP + Kerberos	Open LDAP is the most used alternative to Microsoft Active Directory. It embeds the same characteristics in terms of Users management and authorizations. Coupled with Kerberos for a strong authentication without password exchange, they assume together the authentication/authorization User management over a Domain Controller (acting as a DNS)
Load Balancer	
HA Proxy	HA Proxy is the most used open-source load balancer for applications needing fast response time. It can be interfaced with all premium HTTP Server. Normally, only 1 HAProxy is enough to manage an application (it is not necessary to implement more than 1 HAProxy working in parallel). However, to integrate High Availability, it is strongly recommended to install 2 HAProxy with the KeepAlived technology in goals to manage the failover: in case the HAProxy master would shut down, the HAProxy secondary replaces the master and ensures automatically the load-balancing service
Web Application Firewall	
ModSecurity	The most popular open source WAF. It protects against all attacks listed on the Web. It can be implemented by Apache, Nginx, Microsoft IIS
HTTP Server / Services Exposition Frontal	
Nginx or Apache Server	These 2 HTTP servers monopolize 80% of the world market and are among the most reliable and robust HTTP servers
Enterprise Bus – ETL	
Talend	Talend is one of the earliest open source ETL. As such, Talend performs Extraction, Transformation, loading data, using a base of connectors always renewed: It can be interfaced with almost any storage. It can manage large-scale data flows with very efficient response time.

Open-Source Components Description	
Title	**Role**
	It is an Apache Fundation Partner, which means the Talend developers participate in the development of Apache products, for example Spark (for Big Data processing)
SQL Database	
PostgreSQL	Certainly, the best open source relational database and the most used for managing huge datasets and complex projects; the most complete in terms of functionalities and management. Recognized and appreciated by all developers, it implements an efficient core algorithm which prevents bottlenecks (especially useful for large datasets). It can be praised for its very active community and precise documentation
NoSQL Database	
MongoDB	MongoDB is a document-oriented database that stores the data in JSON-like documents. It is one of the best known and most used NoSQL Database (with Cassandra) for enterprise projects. Associated to MongoDB Compass, it becomes easier to manage MongoDB with its open-source GUI. It allows. ▪ to list and connect databases. ▪ to explore and query data. ▪ to import data ▪ to create aggregation pipelines to process data
Business Intelligence	
Elastic Suite	This is a product for exploring, analyzing and reporting large-scale data. It is composed with: ▪ Elastic Search: search engine for data indexation and data analyzing; it centralizes the data storage and allows a very fast data search and querying (thanks to indexation) ▪ Kibana: user interface for visualizing Elasticsearch data. It can render data as graphs, histograms, pies, dashboards, … ▪ Logstash: the ETL of the suite, it builds server-side pipelines for extracting, transforming and loading data into the storage system Elasticsearch. ▪ Beats: light agents responsible for transferring data to Logstash and Elasticsearch, and facilitating some tasks as Heartbeat, for example, which monitors VM and services availability. The results are passed to Kibana that displays the data in professional GUIs. If necessary, paying less than 15 euros/month, Elastic Suite becomes Elastic Cloud, a fully managed Cloud Service over any Cloud Provider (Azure, AWS, GCP, …) offering HA, Clustering, Data Visualizer, Technical Support, and so on.

The data lake should allow the using of different tools like multiple big data frameworks like Spark, Spark-streaming, Hadoop, Kafka, RabbitMQ, Nifi (list to be validated in task 4.1)

6.3 IoT platform

As a new digital technology included in fourth industrial revolution, the Internet of Things enables machine-to-machine and machine-to-person use cases in all sectors and on a massive scale. How do you connect and manage billions of distributed devices - manufacturing devices, vehicles, mobile or stationary machineries and digital processes - and then transfer, store, and process all of the data these devices produce? The adequate solution requires an efficient IoT platform.

The IoT platform will build an IoT eco-system of objects of the physical world. It allows the digital representation of the devices on the quarry field. For that, it will gather data from the sensors and the expert systems. It is important to remember that the same data could participate in multiple verticals at the same.

The principal responsibilities of the IoT platform are as follows:

- Manages devices and provides communication bindings with devices.
- Helps define business rules using a rules engine. This last defines condition/action relations and provides a routing mechanism of IoT events and message depending on the data arriving on various communication channels.
- Provides different storages solution (temporary vs permanent) and different accessibility patterns (Hot, Warm, Cold)
- Enables the execution of various analytics to create knowledge and generate reports.
- Exposes service APIs for management, supervision, interoperability, and custom application development.

The IoT platform also will enable the development of applications using data from IoT data sources. Segregated into verticals, these applications will cover all the mining processes: Blasting, Drilling, Loading & Transport, Storage, Treatment and Transport. The created applications will enable services that support the smart, sustainable and digital quarry. E.g., H&S, Efficiency, selectivity & profitability, Environmental Impact, Social Acceptance, Autonomous/remote operations, Process control, Advanced analytics, etc.
IoT data will be sent and shared securely in real time (if needed) and with low latency to generate insights and actions to help improve business and processes. The following picture illustrates the IoT core subsystems generally needed for the implementation of Thing, Insight and Actions concepts.

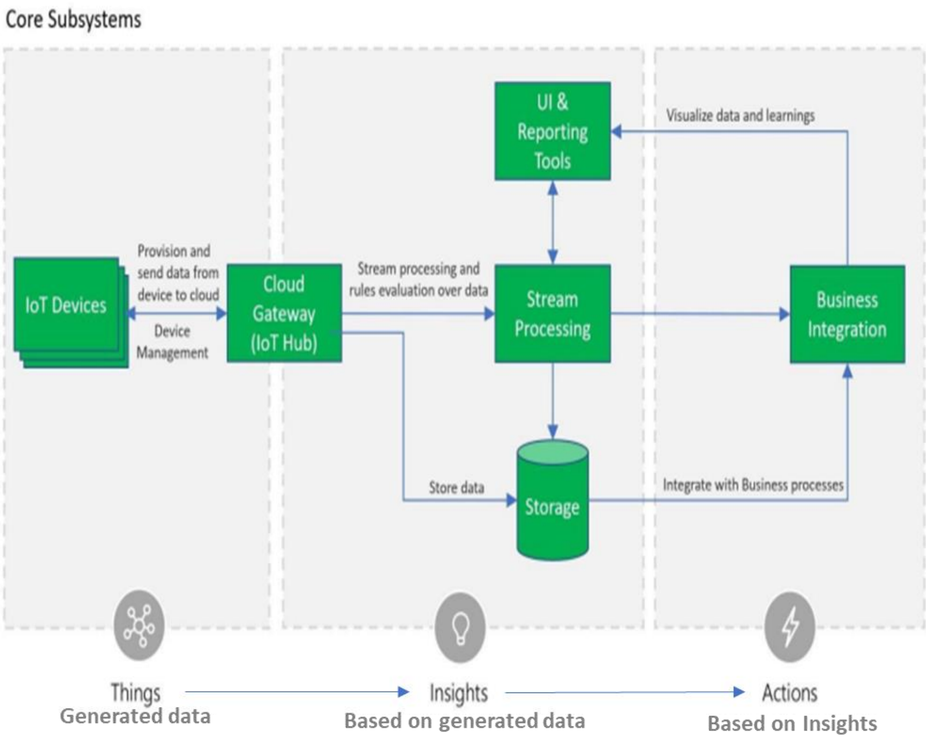


Figure 31: IoT Core subsystems and main principles

6.3.1 Components diagram for the IoT Platform

6.3.1.1 IoT Platform Generic Components Diagram

The generic components are those that any Cloud Architecture implements to make an IoT Platform operable.

Please zoom up to 180 to see the diagram properly.

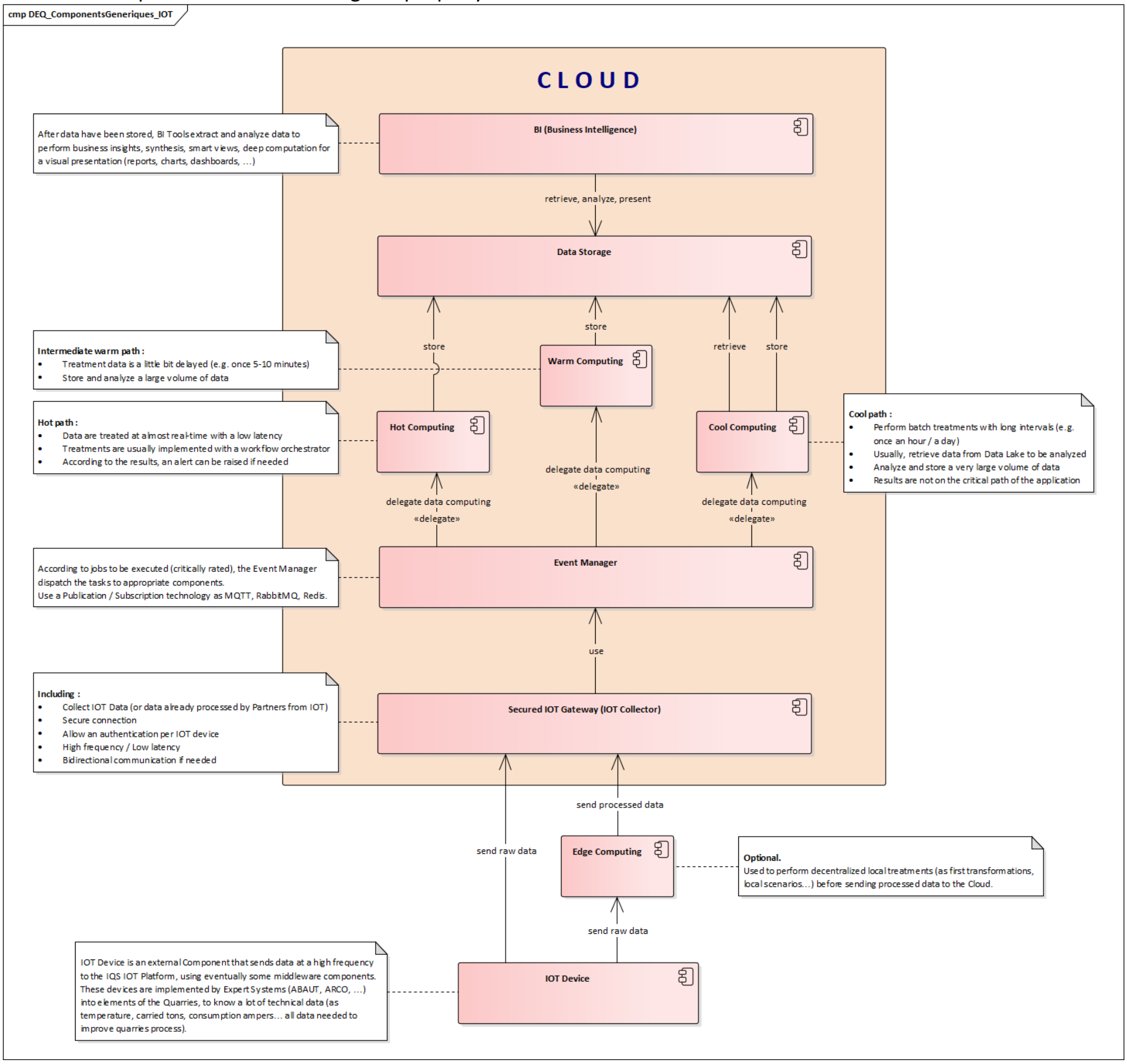


Figure 32: IoT platform generic components diagram

Table 25: IoT Platform generic components description

Generic Components Description	
Title	**Role**
Edge Computing	This component is out of Cloud Platform. It is installed near the IoT Device to execute decentralized computations: it allows to relieve the Cloud Platform of some tasks as local computations, transformations, and so on
Secure IoT Gateway	The IoT Gateway must ensure a highly secure communication between the IoT applications hosted by the Cloud and the IoT Devices that emit IoT Data

Generic Components Description	
Title	**Role**
	It is expected that the IoT Devices can be connected to this component, fully managed and authenticated by this component
Event Manager	This component routes the incoming events to the appropriate tasks to be accomplished (applications, programs, algorithms, and so on) It must offer high availability and scalability according to the traffic flow
Hot Computing	Hot Computing analyzes data at (almost) real time when data flow is entering the Cloud Platform. Data must be processed with low latency. It is typically implemented with a stream processing engine. Example of delay: 1 second to 1 minute
Warm Computing	This is an intermediate computing using to analyze data that may support longer delays for more detailed processing e.g., to store and analyze large volumes of data. Example of delay: 5 to 10 minutes
Cool Computing	Cold Computing performs batch processing at long intervals. It typically applies to large amounts of data that can be stored in a Data Lake, and the results don't need to be as fast as with the other computing. Example of delay: 1 hour, once a day
Business Intelligence	It performs powerful and appropriate analysis over huge data sets and generates a lot of possible and useful visualizations as histograms, charts, and so on…

6.3.1.2 IoT Platform Specific Components Diagram

The following diagram shows the different Cloud Providers' components which could be used by the IQS IoT Platform Architecture.
The components of the main 3 Cloud Providers are presented:

- Microsoft Azure
- Amazon Web Services
- Google Cloud Platform

All these specific components realize the generic components (exposed at the previous paragraph) considered as interfaces to be implemented.

Please zoom up to 150 to see the diagram properly.

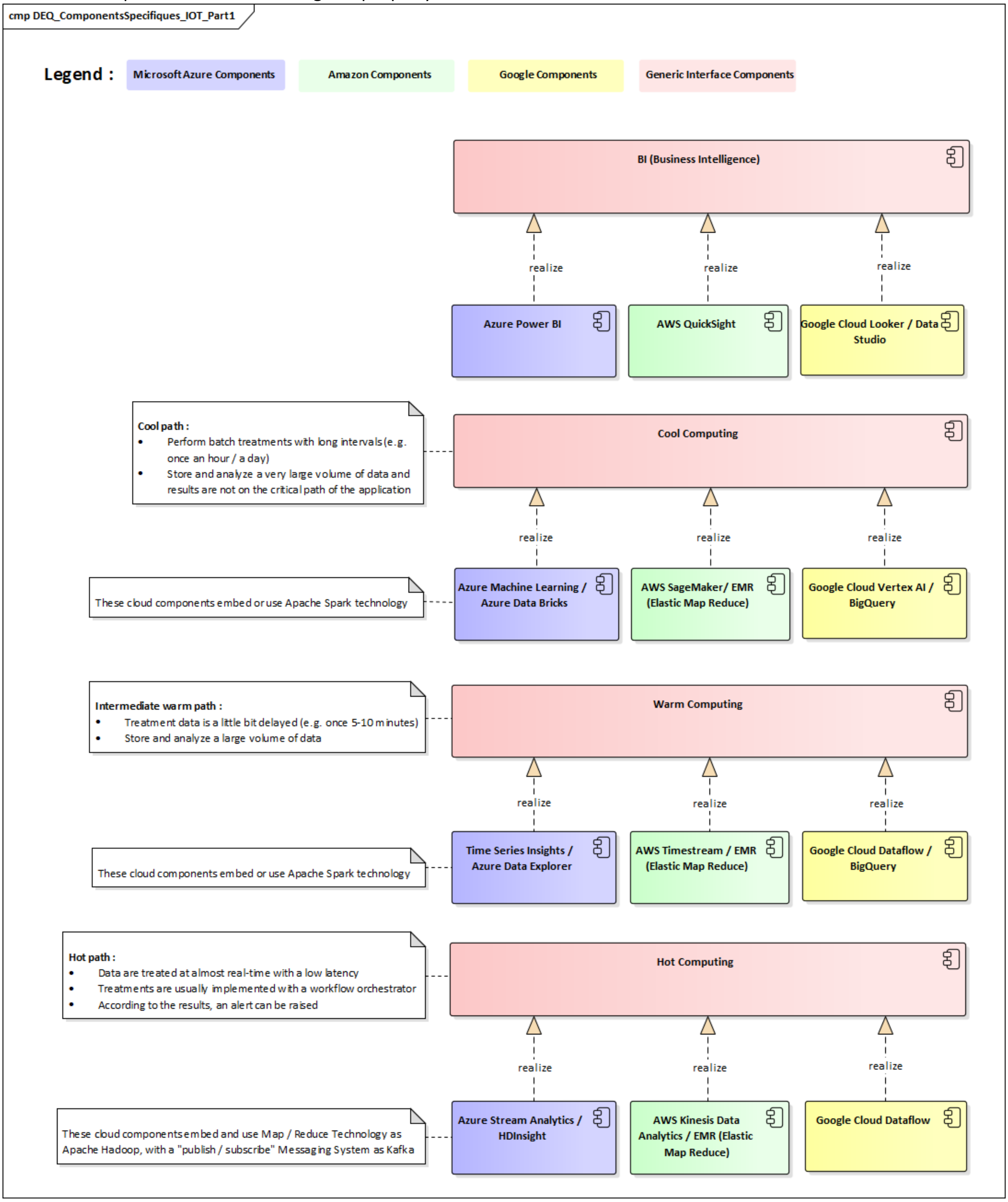


Figure 33: IoT Platform specific components diagram Part1

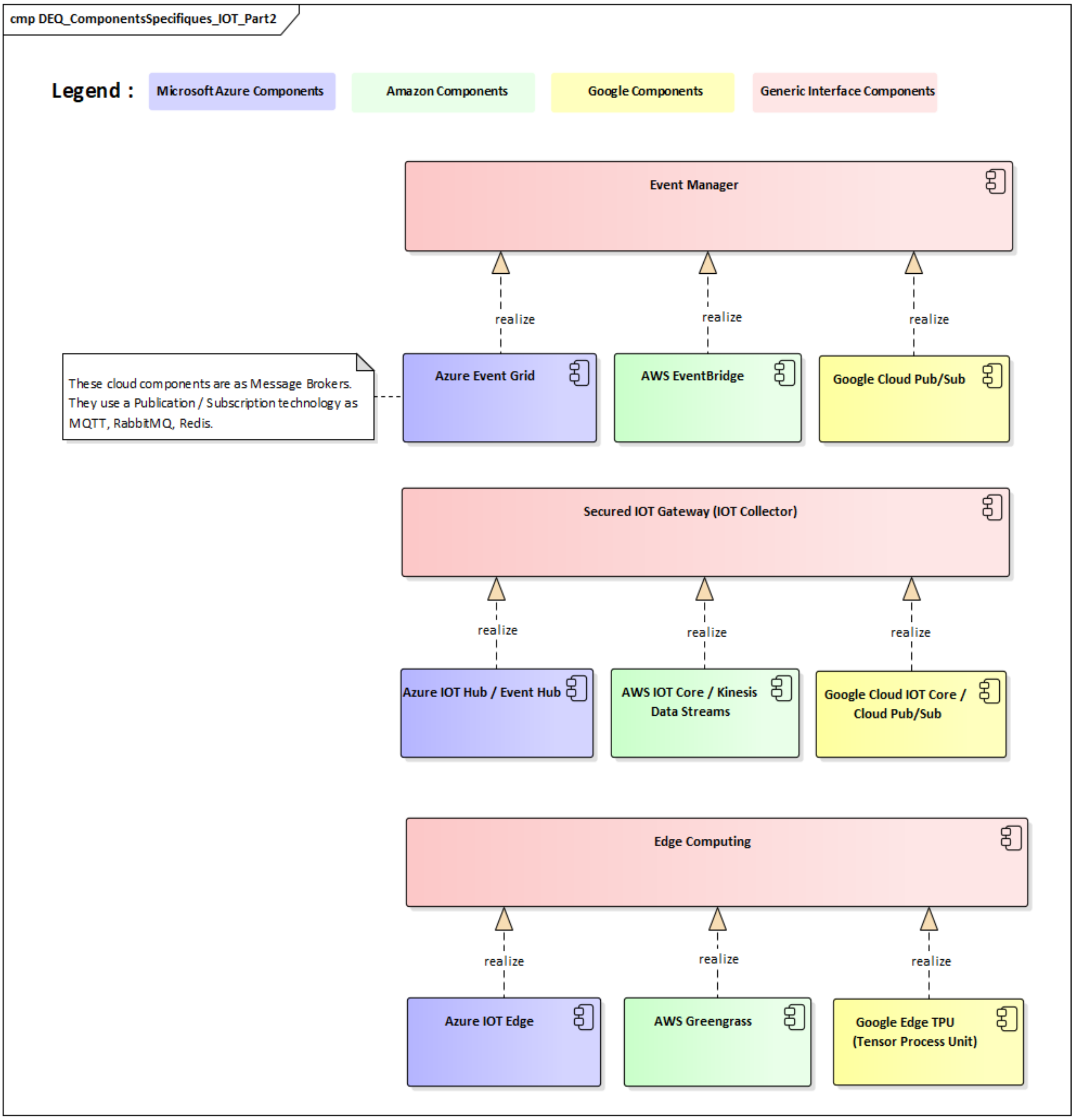


Figure 34: IoT Platform specific components diagram Part2

Table 26: IoT Platform specific components description

Specific Components Description	
Title	**Role**
Edge Computing	
Azure IOT Edge	This component is optional; It does not run on the Cloud but on IOT devices that contact the Cloud.

Specific Components Description	
Title	**Role**
	The main benefit of this component is to be executed locally (offline); it avoids sending too much raw data to be processed over the Cloud; it produces already refined data (generally from several raw data); therefore, it does not consume Cloud resources and optimizes fees and expenses. Moreover, it reacts at real time, as close as possible to the data transmission. And obviously, it embeds a native and efficient connection to IOT Hub/Core over the Cloud; and consequently, it might act as a local gateway by translating the messages to be sent into a protocol understood by the IOT Hub/Core
AWS Greengrass	This component is optional; It does not run on the Cloud but on IOT devices that contact the Cloud. The main benefit of this component is to be executed locally (offline); it avoids sending too much raw data to be processed over the Cloud; it produces already refined data (generally from several raw data); therefore, it does not consume Cloud resources and optimizes fees and expenses. Moreover, it reacts at real time, as close as possible to the data transmission. And obviously, it embeds a native and efficient connection to IOT Hub/Core over the Cloud; and consequently, it might act as a local gateway by translating the messages to be sent into a protocol understood by the IOT Hub/Core
Google Edge TPU (Tensor Process Unit)	This component is optional; It does not run on the Cloud but on IOT devices that contact the Cloud. The main benefit of this component is to be executed locally (offline); it avoids sending too much raw data to be processed over the Cloud; it produces already refined data (generally from several raw data); therefore, it does not consume Cloud resources and optimizes fees and expenses. Moreover, it reacts at real time, as close as possible to the data transmission. And obviously, it embeds a native and efficient connection to IOT Hub/Core over the Cloud; and consequently, it might act as a local gateway by translating the messages to be sent into a protocol understood by the IOT Hub/Core
Secured IOT Gateway (IOT Collector)	
Azure IOT Hub / Event Hub	IOT Hub Basic collects IOT data from IOT Devices, using a secure communication with the protocols HTTPS (HyperText Transfer Protocol Secured), AMQP (Advanced Message Queuing Protocol), MQTT (Message Queuing Telemetry Transport), AMQP and MQTT over Web Sockets. If needed, Azure IOT Protocol Gateway can be used to translate the messages sent by the IOT Devices into a protocol understood by the Hub. Each IOT Device authorized to be connected can be authenticated. Moreover, with IOT Hub Standard, a bi-directional communication can be implemented (for calibration, configuration, device update) Event Hubs is a fully managed real-time data ingestion service, used for a large volume of events and for creating big data pipelines with a graphic representation. It can be interfaced with multiple applications including Apache Kafka
AWS IOT Core / Kinesis Data Streams	IOT Core performs similar tasks as Azure IOT Hub with some specific aspects: ▪ it implements LoRaWAN protocol to allow a low-speed communication with IOT Devices, for low data volume (< 50Kb/s), used by temperature or humidity sensors for example. ▪ it allows to monitor IOT Devices with IOT Device Management ▪ it secures the IOT Devices with IOT Device Defender Kinesis Data Stream is like Azure Event Hub: it allows a continuous data flow absorption, appropriate for a large volume of data to be treated at real time.

Specific Components Description	
Title	**Role**
	Interfaced with Lambda Functions or Kinesis Data Analytics, it allows to treat, transform, refine, compute, ingest data
Google Cloud IOT Core / Cloud Pub/Sub	IOT Core performs similar tasks as Azure IOT Hub with some specific aspects, e.g., it only implements HTTP and MQTT protocols, but offers a protocol gateway for other protocols. Cloud Pub/Sub is Google's Publish/Subscribe Technology, used by any Google Components to communicate asynchronously and to be sure that all clients that have subscribed to a task, perform it. From IOT Core, this Technology is used to dispatch tasks to appropriate components
Event Manager	
Azure Event Grid	This component is used with oriented events applications over HTTP. It is a service to manage events routing and forward the incoming events over any destination component. For this, it uses HTTP protocol and pub/sub technology. It embeds high availability and scalability
AWS EventBridge	Amazon's equivalent of Azure Event Grid is AWS EventBridge, as an events bus that can route any event source to any destination component that will ensure the IOT treatment
Google Cloud Pub/Sub	Google's equivalent of Azure Event Grid is entirely managed with pub/sub technology
Hot Computing	
Azure Stream Analytics / HDInsight	Stream Analytics is a Data Analysis Service at real time (for hot computing) that can create pipelines for data extractions, data analysis, data transformations, alerts… using the familiar SQL syntax. For that, the Data Analysis Service maps the input flow (e.g., a JSON flow coming from Event Hub or IOT Hub) into a "SQLTable-like" that can be accessed using SQL syntax. Then, the extracted data can be transformed, refined and stored into a dedicated storage (BLOB, SQL or NoSQL Table, …). SQL syntax can be extended to some languages as JavaScript or C#. HDInsight is a managed analytics Cloud service, ready to integrate open-source infrastructures as Hadoop, Spark, Kafka... In fact, HDInsight is a Cloud distribution of Hadoop components. As such, it can be used for analyzing data flows at real time for hot computing
AWS Kinesis Data Analytics / EMR (Elastic Map Reduce)	Kinesis Data Analytics behaves like Azure Stream Analytics. Its SQL syntax can be extended to some languages as Java, Python or Scala. EMR is equivalent to Azure HDInsight: it is a Big Data Platform over the Cloud to execute large volumes of data into an open-source analytics frame as Hadoop, Spark…
Google Cloud Dataflow	Google Cloud Dataflow behaves like Azure Stream Analytics. It uses the open-source Apache Beam, programming model to execute – extract, transform, load – data flows into pipelines. SQL Syntax is provided by Dataflow SQL and can be extended to languages as Python
Warm Computing	
Time Series Insights / Azure Data Explorer	Time Series Insights has been designed to analyzed IOT Data. It is used at less or more real time, for warm computing. ▪ It transforms data flows to insights using a Time Series model. ▪ It can be "plugged" natively to IOT Hub or Event Hub for collecting IOT Data ▪ When Time Series Insights is configuring, it can be connected to appropriate storages to save the incoming data and manage data history. ▪ It embeds a compute engine for data analysis.

Specific Components Description	
Title	**Role**
	▪ Combined to Time Series Insights Explorer, it provides visualizations and graphic tools to present analyzed data. Data Explorer is a service for analyzing a large volume of data, which can be used for IOT Data: ▪ It is an all-in-one platform able to ingest, request, visualize, manage data. ▪ It is useful for time series analytics and IOT. ▪ It can use Kusto Query Language (KQL, custom language "SQL-like") to explore and refine data, then return results; it acts as a funnel that filters data using a sequence of queries written in KDL: it is a type of a customized and integrated map/reduce approach
AWS Timestream / EMR (Elastic Map Reduce)	Timestream is a time series database service that can be used for warm computing: ▪ It provides a lifecycle management of time series data by keeping recent data in memory and moving historical data to an optimized storage-tier based on user defined policies. ▪ It embeds a customized query engine that allows to access recent and historical data, and a combination of both. ▪ It provides an integrated time series analytics functions answering to frequently asked questions. EMR can either be used for hot or warm computing
Google Cloud Dataflow / BigQuery	To create a pipeline for IOT Data Analytics, Google Cloud mainly uses Dataflow (hot and warm computing) and publishes results into the datawarehouse BigQuery. To publish into BigQuery, the Pub/Sub Technology is used. It does not exist a specific Time Series offer for Google Cloud. GCP BigTable is the natural candidate to implement a Time Series database
Cold Computing	
Azure Machine Learning / Azure Data Bricks	For cold computing, it is generally accepted to run Machine Learning that retrieves a large volume of data from a Data Lake, produces analyzed data, then stores these analyzed data into a Data Lake Data Bricks allow to create Big Data analytics solutions based onto Apache Spark, for a large-scale data processing for batch and streaming workloads
AWS SageMaker / EMR (Elastic Map Reduce)	Amazon's Machine Learning offer is SageMaker. EMR can process a large volume of data using Spark, therefore it can be also used for a cold processing
Google Cloud Vertex AI / BigQuery	Google's Machine Learning offer is Vertex AI Data produced by Vertex AI are the most often stored into BigQuery
Business Intelligence	
Azure Power BI	Power BI retrieves significant data from a large dataset and transforms them into relevant visual reports into dashboards. Power BI can embed data coming from many data sources: structured files as Excel files, Relational Databases, Dataflows, all Azure Components. Power BI Desktop is the graphic interface that displays data reports. It is downloaded locally on desktops. Moreover, Power BI uses an incremental refresh for datasets to exploit and render data into always up-to-date reports (for warm or hot computing). To do that, it can manage automatized partitions of database tables. However, this technology is subject to limitations or constraints, with implementation difficulties: it works better with Azure SQL Database, Azure Synaps or SQL Server, and more easily with relational databases than with no-SQL databases, the tables to be mapped for

Specific Components Description	
Title	**Role**
	reports must be structured in a certain way, the development requires some skills, etc. Data to be treated by Power BI can be imported into Power BI Desktop (Console Graphic Tool) or accessed directly, each time when needed, by DirectQuery (if the used Database is compliant with DirectQuery)
AWS QuickSight	QuickSight is the Amazon's BI platform. It works similarly as Azure Power BI with some specificities. QuickSight uses the Data Engine SPICE (Super-fast, Parallel, In-memory Calculation Engine) to compute data in memory. SQL Databases, Time Series or Data Lake (Amazon Simple Storage Service) can be accessed It integrates a natural language (named Q) to request the datasets
Google Cloud Looker / Data Studio	Data Studio runs inside a navigator and works with a strong active community. It connects to many data sources and all the Google Cloud Components; it is used to build dashboards. Looker is a more complete tool: it is also used to aggregate data before reporting. The tool must be downloaded on a station and is closer than Azure Power BI Desktop and Amazon's QuickSight

6.4 Data Warehouse

The Data Warehouse is an integral part of the IQS and will be used to store optimised and processed data from the data lake and expert systems, these are what is normally called the Data Warehouse source systems. The Data then will be extracted in order to be presented in Dashboards for the end users authorized by the different Quarries. Below a general conceptual architecture is displayed. A benchmark will be implemented in order to decide which implementation to use in the project. There are many solutions in the market as it is the case for the Datalake.

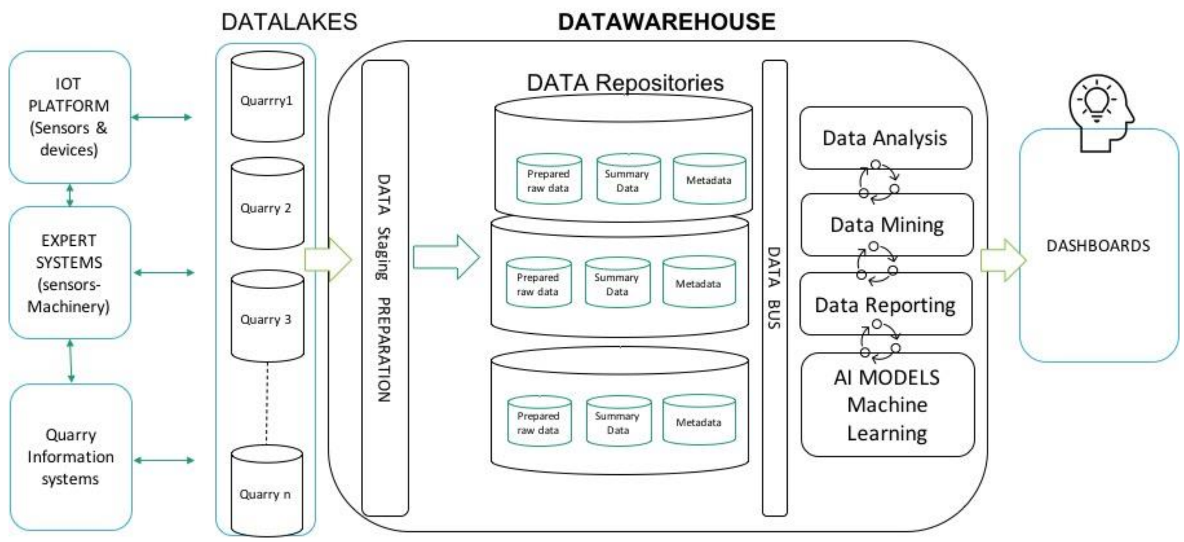


Figure 35: Datawarehouse Architecture Concept

The principal functions of the Data Warehouse will be to select the data stored on the Datalakes linked to their corresponding Quarries and if needed pre-process the data in order to get good data quality and sufficient information to be further processed by the different data related operations and Artificial Intelligence models. In modern Artificial Intelligence implementations, the code, the analysis and the models used or developed are not as important as the data

itself that is processed. It has to be properly filtered, selected and tagged. That is why the DataWarehouse will be organized in different data repositories as represented in the Figure 35. These repositories will be linked to the different quarries from one side and will be also linked to the type of insights that the IQS has to generate for the users in the optimisation of quarry operations. These repositories and commonly named as data marts.
The datawarehouse is the element of the IQS that ensures a proper data management targeting the recognition of data patterns that lead to helpful predictions and leverage the decision making processes to better manage the business of quarries, to detect possible risks, to reduce consumption of energy, to improve environment sustainability, to capture in a friendly and timely manner the right information for the different roles of the Quarry personnel, to improve the use of the machinery allowing for better maintenance procedures, to optimize each of the processes in the quarry to guarantee an optimal stock and production management.

6.4.1 Component descriptions of the Datawarehouse

Below a table is appended with descriptions of the main components of the DataWarehouse:

Table 27: Main components of the DataWarehouse

Generic Components Description	
Title	**Role**
Data Staging Preparation	The formats and the data available in the Datalakes are unstructured and have different formats. The Data Staging block will take the data from the datalake and will make a selection of it and a preliminary filtering. Finally, the analyzed data will be loaded in the Data Warehouse repositories
Data Repositories	Data will be organized within the Datawarehouse in different repositories. The latter will be assigned different purposes and characteristics in order for the processing blocks to easily access in an optimal way the data they will need. The repositories may be assigned each one to different quarries and related operational and characteristics definitions. These will be defined precisely in WP4 having in mind the specifications of the AI services, data to be used and the results and KPIs to be displayed on the various dashboards that will be fed by the Datawarehouse. Such Dashboards will be oriented to manage business issues of the quarries, risk detection, Maintenance operations, etc… The Data will be organized in basically three different formats: Preprocessed Raw data, meaning the selected data without any important format transformation. Summary data, which will be related to the latter and will be the result of the analysis, mining and AI models post processing. And finally, there will be a separate store of metadata that will keep useful information about the latter 2 stores in order to better classify the data with different properties (types, formats, time stamps, representation, etc…)
Data Bus	The Data Bus will be simply used to connect the data processing blocks to the different repositories. It is a logical representation. The "Bus" will be able to accommodate many different formats and lengths depending on the data that will be made available on the repositories
Data Analysis	This is the data processing block that is used to get insights from the data that it processes. It can calibrate if the data is relevant for different types of analysis, for example if it is a temperature of a machine, it defines if it is a normal temperature or if it falls within ranges that indicate bad performance, over use of the machine, etc… The results of the analysis can be extracted directly to the external dashboards after a query or may be stored on the repositories to be later used by other post-processing blocks
Data Mining	This is the data processing that is based on the use of Mathematical and scientific methods to identify patterns or trends over the data that it handles. This step is very useful for predictions about the type of data it analyses: if it analyses the

Generic Components Description	
Title	**Role**
	quantity of material production for example it can identify issues in the processing steps of a quarry for example. It can help to better plan for the transport of the material or on how the material can be stored in the plant
Data Reporting	This block will be gathering all the queries from the external users of the Data Warehouse. It will decide which process to be carried out on the data or commands as chosen by the user at the interface. It can extract data from the repositories or use the metadata to better respond to the query
AI Models Machine Learning	For DEQ a set of Machine Learning models will be developed and applied to solve different issues or problems, to calculate important KPIs, to make predictions on specific functions such as predictive maintenance over different machines in given processes, to evaluate risks along the quarry processes, etc. Here the expertise of the Quarry experts is needed to be able to select the data that can better used to train these models in order to feed them with the best examples of the problems we want to detect or solve with the models. The better the preselection of data is, the better the results of the machine learning models will be

6.4.2 Market analysis of datawarehouse implementations

Among the most popular solutions in the market, we can mention:

1. Amazon Redshift,
2. Google BigQuery,
3. Snowflake and the
4. Microsoft Azure solution for warehousing.

Below a comparison [1] is summarised for the first three solutions in order to understand how implementations can vary on some of the basic concepts such as: The computer layer uses, the storage layer, Compression, Deployment, Pricing, Scalability, Data Access, etc.

6.4.2.1 Computing Layer

- Bigquary: runs on a distributed infrastructure laid down by Google that is called Borg.
- Redshift: Runs on AWS virtual Machines using a fork of parAccel
- Snowflake: Uses a proprietary computing engine with pushdown and smart caching features; it runs on commodity virtual machines (AWS, GCP or Azure)

6.4.2.2 Storage Layer

All of the solutions typically implement hot, warm and cold internal storage.

- Bigquery: Uses a proprietary solution using a Colossus filesystem using ColumnIO as format. It separates the computing layer form the storage layer.
- Redshift: Depending on the computing needs, Amazon offers three types of nodes SSD, HDD or RA3(Proprietary columnar format with extensive cache)
- Snowflake: Uses a proprietary Columnar format, in memory, SSD for object store running on the cloud chosen. Data is stores in columnar format with caching.

6.4.2.3 Compression

- Bigquery: Uses a proprietary compression hidden to the user. The compression is made automatically for you and queries are implemented without burdening the users on how data is compressed. They function as if data was stored with the original format.
- Redshift: Achieves transparent compression using open compression algorithms. You can select what parts (columns) of your data have to be compressed. The compression algorithm can be changed at will without requiring making copies.
- Snowflake: Also provides opaque compression to its users. The query planner can take advantage automatically of the compression method to scan less data and reduce computing costs. The new compression methods are being applies without burdening the users.

6.4.2.4 Deployment

All of these Data Warehouse implementations follow a cloud-only deployment strategy.

- Bigquery: Deployment occurs within the Google Cloud Platform having in mind its specific features and requirements.
- Redshift: Deployment occurs within the Amazon Web Services infrastructure following its specific rules and features
- Snowflake: Deploys over AWS, Google or Azure solutions depending on needs and “tastes”. Not all regions are supported as of now; this is an important issue to consider.

6.4.2.5 Pricing

The cost of the Data Warehouse products has a fixed or variable cost strategy depending on the plan the user choose.

- Bigquery: The first pricing model is fixed storage, bytes scanned, slots and streaming inserts. The second model is on-demand pricing is based on bytes scanned whilst you can purchase fixed slots. The price may vary per region.
- Redshift: It sets a price depending on the mode type used (ds2, dc2 or RA3), number of nodes, reservations. Add-ons such as certain features (Redshift Spectrum, consurrancy scaling) incur in extra costs. Node cost vary per region.
- Snowflake: The product price depends on the plan chosen (certain features), the number of warehouses and their sizes. The latter will get what they call a cost per credit. This will vary per region, on the plan and the cloud provider chosen. It is possible to purchase capacity storage to get a more predictable price.

6.4.2.6 Data Access

- Bigquery: ODBC, JDBC via Simba drivers, user interface, APIs, command line tool.
- Redshift: ODBC, JDBC via AWS provided drivers, user interfaces, Data access API, via the AWS command line interface and via Postgres command line tool
- Snowflake: ODBC, JDBC via drivers, Spark plug in, Kafka, Python / Node.js / Go / .NET / PHP PDO drivers, Snow SQL command line tool, SQL API (Restful) or via Snow park

6.4.2.7 Encryption

All products offer some method in static and in motion modes.

6.4.2.8 Third party tools and query languages

All solutions provide support for the most used in the market visualization tools. Aws and Google Cloud Platform have their own general access visualization. Snowflake tends to put in front their own “Snow” tool: Snowsight.

As for query languages, they are SQL ANSI compliant. But all of the solutions have extra features that may suit advanced users.

[1] https://poplindata.com/data-warehouses/2021-database-showdown-bigquery-vs-redshift-vs-snowflake/

7 Conclusions

To establish the **requirements for the quarry full digitalisation**, i.e. for Smart Sensors, Automation and Process Control and for BIM, AI and ICT solutions, the contributors of this D1.3 deliverable analyzed the current situations of the **five pilot sites** as reported by **ANEFA** after their visits of these sites. Based on these analysis results and on the definition of actions within the Grant Agreement, the contributors defined the possible solutions to be implemented to allow the **DigiEcoQuarry project** to achieve its objectives.

Within KTA3.1, **ARCO** and **MAESTRO**, for Vicat and Holcim, will be able to generate in near real time measurement data to control and monitor machinery performance. For that, sensors will be set up on the different plant machineries (crusher, conveyor, screeners…) and connected to a treatment plant system based on program logic control and graphical interfaces.

Within KTA3.2, **ABAUT** will develop for the mobile machinery fleets of almost all the pilot sites, for their internal as well as their external transport processes, equipments and systems that enable the real-time positioning and the management of the mobile machinery fleet (all aspects: efficiency, environment, safety…), the traceability and the reporting about the material and the recognition for workers nearby mobile quarrying machines.

Within KTA3.3, **DH&P** will develop a set of IoT devices, hardware and software for CSI's mobile equipment in order to record, monitor and analyze their mobile machinery data. In particular, DH&P will enable CSI, mainly in the scope of the loading and hauling processes, to monitor and manage any of their mobile machinery on any aspect (efficiency, environment, safety…), to get the real-time positioning and mapping of their mobile equipment, to trace their material from the extraction points to the primary crusher and to produce automatic reports.

For all pilot sites, these technological solutions on the field will be supported by BIM, AI and ICT solutions in the cloud.

Within KTA4.1, **APP** will apply and develop BIM process and solutions. Thanks to this integrated system of applications allowing the interoperability of data, the quarries will benefit of a unified asset information model, connecting BIM applications with quarries data. Quarries will get 3D visualization of their projects, conflicts visualization, time planning and works execution optimization as well as resource and cost optimization.

Within KTA4.2, **SIGMA** will develop artificial intelligence algorithms and modelling, trained by pre-processed data stored on a data warehouse. The quarries will access to several dedicated applications in order to optimize, monitor and help in the decision-making processes, such as preventing the accidents, predicting maintenance operations, managing the production stocks, managing information about customer demands, market prices, optimal handling of orders, etc…

Within KTA4.3, **AKKA** will create the IQS to integrate all these applications. For that, dedicated and configurable data lakes as well as IoT platforms, when necessary, will be deployed for each quarry. The data lakes will be centralized and secured repositories to allow the ingestion, the storage, the analysis and the usage of all relevant data. The IoT platforms will enable quarries to bind and manage their devices, they will help them to define business rules allowing condition/action relations and generating IoT events and messages. The integration with the IQS will be performed thanks to several connectors developed by data providers. These solutions will enable the development of various scenario that leverage any data shared by all KTAs and also the development and integration of business management tools (KTA4.4)
To support these ICT solutions in the cloud, a state of the art on the data lakes, IoT platforms and data warehouses has been done and reported in section 6; it provides a first analysis of the digital technologies that should be used to build the future intelligent digital quarry system. This analysis will be completed by a benchmark study in the frame of the task 4.1.

This deliverable 1.3 is a major input document for the work to be done as planned in WP3 for the "Development of sensors, automation and process control [KTA3]" and in WP4 for the "Development of an integrated IoT/BIM/AI platform for smart Quarrying (KTA4)".

8 References

Document Resource ID	Document Resource name and reference
DR1	EU Grant Agreement n°101003750
DR2	D1.1 Requirements for Improved extraction, rock mass characterisation and control report
DR3	D1.2 Requirements for Innovative Treatment processes
DR4	D1.4 Requirements for H&S improvement, Environmental impact minimisation and energy and resources efficiency report
DR5	D3.1 List and characterisation of key data inputs

9 Annexes

9.1 CSI comparison of the state 0 and the to-be situations

CSI	State 0	To-be	
	Description	**Description**	**Requirement_ID**
KTA3.3 Mobile equipment & quarry geological deposit digitalisation & real-time modelling			
	CAN Bus data from OEMs are not used in a central system. Some machine data are available via OEM systems.	The expert system must work with CAN Bus data from different OEMs	T1.2_KTA3.3_1
	There are no data loggers installed on the mobile equipment.	The expert system must record data from different sensors installed on the mobile equipment using a data logger	T1.2_KTA3.3_2
	Mobile equipment data and manual input data are not combined.	The expert system must combine data from mobile equipment with additional manual input data	T1.2_KTA3.3_6
	On-board GPS systems and TomTom systems are installed on the trucks. No RTK available. Evaluation possibilities are low.	The expert system must provide real-time kinematic positioning of the mobile equipment	T1.2_KTA3.3_7
	Fuel consumption is validated with OEM systems and at the fuel station.	The expert system must provide the fuel consumption of each mobile equipment	T1.2_KTA3.3_8
	Currently there is no or just a manual information about the performed activities for each machine.	The expert system must provide the activities performed of each mobile equipment	T1.2_KTA3.3_9
	No information about the machines status.	The expert system must provide the status of each mobile equipment	T1.2_KTA3.3_10

CSI	State 0	To-be	
	Description	Description	Requirement_ID
	The geofences need to be developed.	The expert system must integrate 3D geofences to link the mobile equipments position with its activity	T1.2_KTA3.3_11
	The total production is given from manual inputs.	The expert system must provide production from mobile equipment	T1.2_KTA3.3_12
	No information about the driving speed.	The expert system must provide driving speeds of mobile equipment	T1.2_KTA3.3_13
	No information about driven distances.	The expert system must provide distances driven by the mobile equipment	T1.2_KTA3.3_14
		The expert system must provide tyre pressure of mobile equipment	T1.2_KTA3.3_15
		The expert system must provide tyre temperature of mobile equipment	T1.2_KTA3.3_16
	Available for some machines via OEM systems.	The expert system must provide the engine operation mode of mobile equipment	T1.2_KTA3.3_17
	The cycles are documented manually.	The expert system must determine cycles performed of mobile equipment	T1.2_KTA3.3_18
	No information about the used gear, data from OEM systems.	The expert system must record gear usage of mobile equipment	T1.2_KTA3.3_20

10 List of Figures

Figure 1: Sensors view in a treatment plant. 20
Figure 2: Plant view by remote in real time 22
Figure 3: Logical scheme for data transmission 22
Figure 4: sView - mView 23
Figure 5: abaut Edge 23
Figure 6: Datalogger 25
Figure 7: Example of the lifecycle information management diagram 28
Figure 8. Example of Mining and Quarry Planning 29
Figure 9. Example of Mining and Quarry Planning including Time-Chainage Planning 30
Figure 10. Example of BIM lifecycle Data Management 31
Figure 11. Example of COBie exchange in BIM 32
Figure 12: AI principles architecture 35
Figure 13: Use cases overview regarding the AI Services (KTA 4.2) 41
Figure 14: Risk Detection (RiQ) use case diagram 41
Figure 15: Predictive maintenance (PrMa) use case diagram 42
Figure 16: Metaquarry use case diagram 42
Figure 17: IQS, Data Lake and IoT actors 46
Figure 18: Use cases dedicated to the IQS Administrator role 47
Figure 19: Use cases dedicated to the IQS System Integrator role. 47
Figure 20: Use cases dedicated to the AKKA CICD role. 48
Figure 21: Use cases dedicated to the AKKA development team role. 48
Figure 22: Use cases dedicated to the data lake administrator role 53
Figure 23: Use cases dedicated to the data lake user role. 53
Figure 24: Use cases dedicated to the IoT Administrator role 55
Figure 25: Use cases dedicated to the IoT user role 55
Figure 26: Global IQS architecture 61
Figure 27: Data Lake global architecture 62
Figure 28: Data Lake generic components diagram 63
Figure 29: Data Lake specific components diagram Part1 65
Figure 30: Data Lake specific components diagram Part2 66
Figure 31: IoT Core subsystems and main principles 71
Figure 32: IoT platform generic components diagram 72
Figure 33: IoT Platform specific components diagram Part1 74
Figure 34: IoT Platform specific components diagram Part2 75
Figure 35: Datawarehouse Architecture Concept 79

11 List of Tables

Table 1: List of the other deliverables of the WP1 ... 8
Table 2: Treatment plant stages ... 16
Table 3 List of the requirements for KTA3.1 ... 17
Table 4 List of the sensors for KTA3.1. ... 17
Table 5: Treatment Plant KPIs ... 19
Table 6:Machinery List and Deliveries ... 20
Table 7: Use Case ... 21
Table 8: KTA Requirements ... 23
Table 9: List of KT A & KPIs ... 24
Table 10: Requirements for the implementation of KTA 3.3 ... 25
Table 11: Use Case Description of KTA 3.3 ... 26
Table 12: Requirements for implementation ... 33
Table 13: Use Case Description ... 34
Table 14: Requirements for the implementation of the Artificial Intelligence services ... 37
Table 15: Artificial Intelligence services use cases. ... 39
Table 16: List of the requirements for the global integration and the IQS ... 43
Table 17: List of the use cases for the global integration and the IQS ... 49
Table 18: List of the use cases for the Data Lake ... 53
Table 19: List of the use cases for IoT Platform ... 55
Table 20: List of the requirements for the global integration and the IQS ... 57
Table 21: List of the use cases for the Business Management tool ... 59
Table 22 : Generic Components Description for a Data Lake ... 63
Table 23: Specific Components Description for a Data Lake ... 67
Table 24: Data Lake Alternative Components (Open Source) ... 69
Table 25: IoT Platform generic components description ... 72
Table 26: IoT Platform specific components description ... 75
Table 27: Main components of the DataWarehouse ... 80