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DIGIECOQUARRY
INNOVATIVE DIGITAL SUSTAINABLE AGGREGATES SYSTEMS

Horizon 2020 research and innovation programme (Nº 101003750)

Deliverable D1.2

Requirements for Innovative Treatment Processes

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Deliverable report

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List of Abbreviations

Abbreviation	Description
BIM	Building Information Modeling
CA	Consortium Agreement
CFS	Certificate on the Financial Statements
DoA	Description of Action
EB	Exploitation Board
EC	European Commission
GA	Grant Agreement
H&S	Health and Safety
IFS	Individual Financial Statement
IQS	Intelligent Quarrying system
KPI	Key Performance Indicator
KSA	Key Social Area
KTA	Key Technology Area
LCSI	Local Crushing/Screening Interface
MoM	Minutes of Meetings
PFSIGN	Project Financial Statement
PLC	Programmable Logic Controller
PRC	Project Research Committee
PSD	Particle Size Distribution
RMC	Resource Monitoring and Control
RP	Reporting Period
SCADA	Supervisory Control and Data Acquisition
SW	Software
WP	Work Package

1 Background

The scope of the WP1 is to define the requirements of the smart, sustainable digital quarries in compliance with European strict legal and environmental requirements. The target is to:

- Ensure that all the objectives are related with the definition of the specific requirements for the global project and particularized for each pilot site and for each aggregates production process.
- Ensure that all requirements will be defined with a detailed characterization of critical processes along the quarrying value chain.
- To define specific requirements for each Key Technology Area (KTA).
- To specify the requirements for the evaluation of the degree of fulfilment of the project's objectives.

This report focuses on all plants with processing and treatment of materials. The target is to ensure that all the objectives are related with the definition of the specific requirements for the global project and particularized for each pilot site and for each aggregates production process. To do that, an evaluation of the initial starting infrastructure and services (state 0) of pilot sites is needed. This will allow a fair measurement of the progress of each site after the project by a final evaluation of the progress achieved.

The T1.2. task will define the requirements for a sustainable, safe, and efficient site treatment processes, following these steps:

- Actions & proposals for a sustainable management of environment protection, climate change prevention and ecological transition.
- Actions & proposals to optimize the management of the extraction process to increase efficiency and productivity, including H&S and social acceptance.
- Assessment of all available techniques, testing and evaluation of feasible techniques.
- Network infrastructures and interactions between the different technologies, AI, BIM, Digitalization, IoT, expert systems, sensors, and machines.

The KTAs defined with different development areas are shown in the Figure 1. The relevant KTAs with development targets of each quarry are listed with the summary of the technologies to be used.

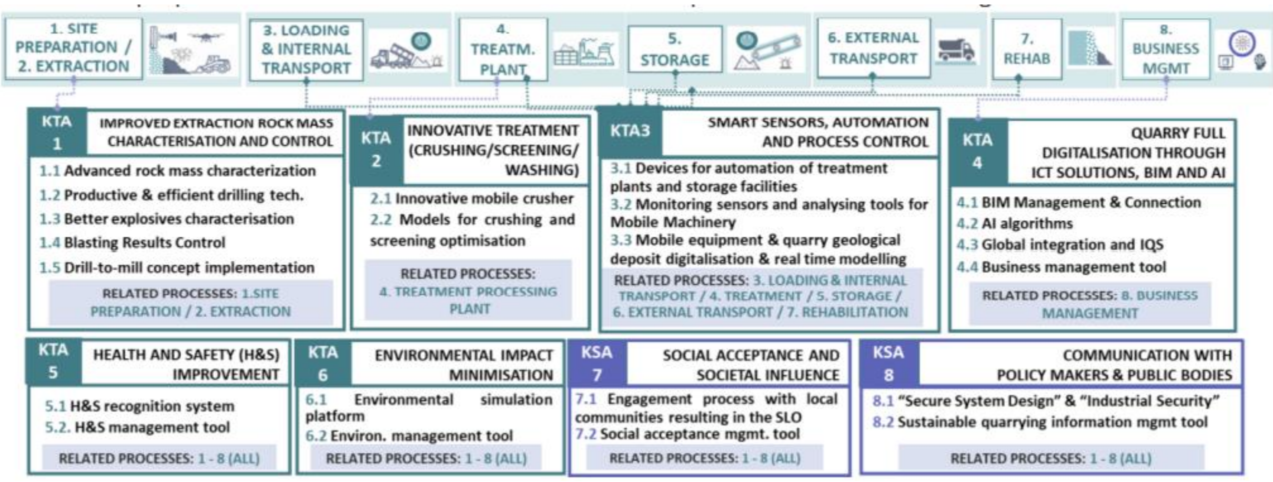

Figure 1 - DEQ KTA Development targets

1.1 Description of HANSON Valdilecha quarry

Hanson Hispania (HANSON) is a subsidiary of HeidelbergCement, which is the leading aggregates producer in the world with around 55,000 employees at more than 3,000 production sites in more than 50 countries on the five continents. The core activities of HeidelbergCement include the production and distribution of cement and aggregates. Its downstream activities include mainly the production of ready-mix concrete, asphalt, and other building products.

Concerning membership and clustering, HANSON is member of UEPG (European Aggregates Association), ANEFA (Spanish Aggregates Producers Association), Oficemen (Spanish cement association), Cembureau (European Cement Association), Anefhop (Spanish ready-mix concrete association), GCCA (Global Cement and Concrete Association) and, additionally, partner of BirdLife International.

1.1.1 Overview of the plant and main products

Among Hanson's several active sites, Valdilecha Quarry located in the Southeast of Madrid province has been chosen as a pilot site for Digiecoquarry project, as it has been used as a testing site for many company projects in the past years. An overall view of the quarry is given in Figure 2. Operation's start year is 1998 and operation's predicted end year (according to permit) is 2051. The quarry has limestone production, annually 1 200 000 tons. The types and annual amounts of the products are presented below in Table 1.

Table 1 – Annual production of HANSON Valdilecha quarry

Product type	Annual production (tons)
Armourstone	1 823
Coarse aggregate (< 32 mm)	223 080
Coarse aggregate (1mm - 32 mm)	301 515
Sand (< 4 mm)	188 569
All in 0 - 1 mm	599 284

Figure 2 – Aerial view of the HANSON Valdilecha quarry

1.1.2 Material transport methods and measurement systems

Transport from front to plant is done by trucking and average distance travelled by trucks from face to plant feed is 765 m. Materials transport is done by conveyors in treatment plant. A total number of 16 mobile machine units are in use at the site. The mobile machinery utilized at the quarry is presented in Table 2:

Table 2 – Material transportation equipment utilized at HANSON Valdilecha quarry

Wheel loaders	Trucks	Excavators
Komatsu WA420	Perlini 131-33E	Liebherr A934B
Caterpillar 988F	2x Komatsu HD405-6	Komatsu PC750SE-7
2x Caterpillar 980G	4x Komatsu HD605-7	Caterpillar 390 FL
Caterpillar 980GII		
Caterpillar 980M		

In the last years, the company is strongly engaged in the automation and digitalization of all production activities. HANSON is both globally and locally rolling out an ambitious project AOM (Automated Operations Management) where all employees record their activities through mobile phones (start and finish times of any activity), fuel consumption and other crucial data i.e., breakdowns, cycle time, sock management volumes, etc.

Mobile and fixed machinery are also equipped with sensors to record fuel and electricity consumption, idle time, availability and breakdowns, with root cause and assets to identify bottlenecks. Geopositioning is used, and also, machines are equipped with sensors (provided by abaut). The following process measurement systems are in use:

- Automatic fuel consumption measurement.
- Capture real-time 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.

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. For dumpers, excavators, 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.

1.1.3 Energy and water usage

The total energy and water usage at the HANSON Valdilecha quarry per annum are listed in Table 3. The main use for diesel is transportation machinery. Electricity is used for running the crushing plant, and water is used primarily for dust control in the plant and domestic use.

Table 3 – Annual resource usage at HANSON Valdilecha quarry

Resource	Usage (per annum)
Diesel	670 930 l
Electricity (from distribution grid)	1 792 102 kWh
Water (surface)	200 000 m^3 (estimated)
Water (groundwater)	400 000 m^3 (estimated)
Water (total)	600 000 m^3 (estimated)

1.1.4 Processing methods (crushing and screening equipment and monitoring systems in the plant)

Flowchart of the Valdilecha crushing plant is displayed in Figure 3. From the figure it is seen that the process is fed with a wheel loader. The material is first screened, and the natural fines are screened further into 0/40 mm and pre-stocked. A jaw crusher is the first and only crushing stage, and the crushed material is screened into 0/30 mm and 40/90 mm piles. The plant consists of conveyors, crushers, feeders, screens, and pumps (for water treatment).

HANSON has implemented a digitalized Preventive Maintenance Management system where all repairs and breakdowns are recorded, and all preventive maintenance activities are explained with detailed instructions. The system manages different KPIs such as time and cost of corrective/preventive actions for each resource, type of defect and cost of spares.

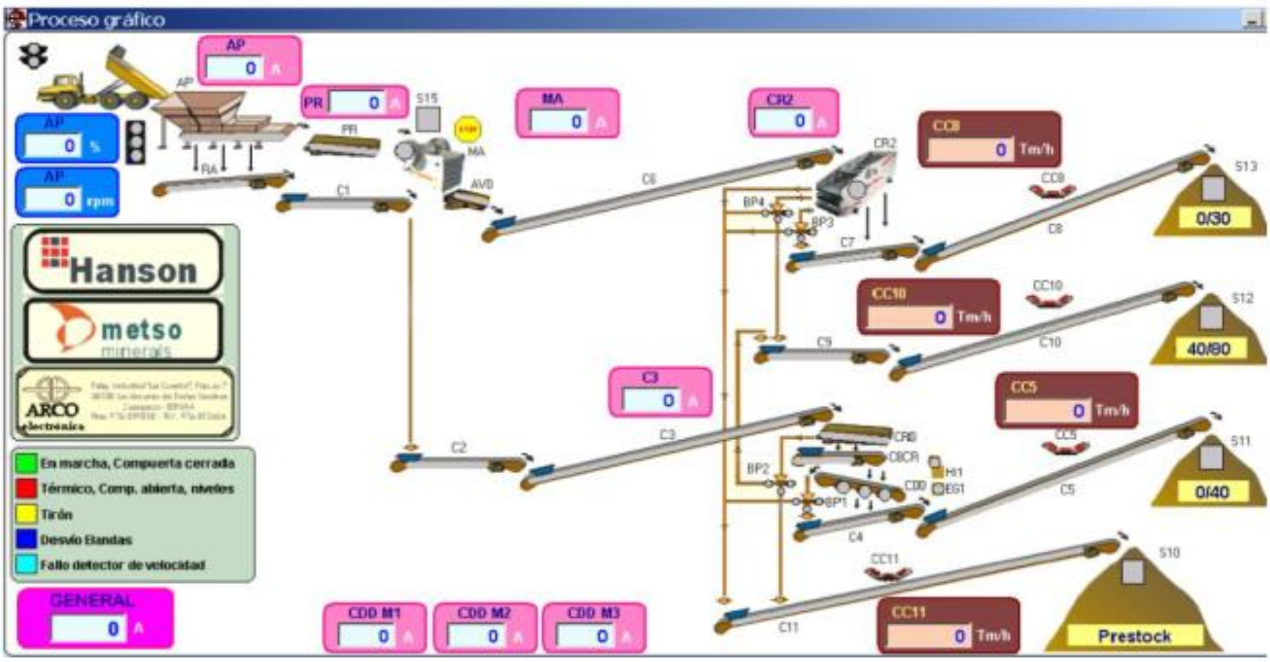

Figure 3 – HANSON Valdilecha quarry flowchart.

1.1.5 Development targets in DigiEcoQuarry

Below, the KTAs for the HANSON Valdilecha quarry and their respective partners are listed.

- KTA1.1 Advanced rock mass characterization (REFERENCE PILOT) - UPM-M, MUL, MAXAM, SANDVIK, ABAUT
- KTA1.2 Hydraulic top hammer drilling technology (REFERENCE PILOT): SANDVIK
- KTA1.3 Better explosives characterization (REFERENCE PILOT): MAXAM, UPM-M, MUL
- KTA1.4 Blasting results control (REFERENCE PILOT): MAXAM, MUL, UPM-M
- KTA1.5 Drill-to-mill (REFERENCE PILOT): MAXAM, UPM-M, SANDVIK, ABAUT, MUL
- 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

1.1.6 Summary of technologies to be developed

This pilot will lead the implementation of KTA1, i.e. rock mass characterisation techniques to target drilling and blasting optimisation, drilling accuracy analysis. Additionally, implementation and testing of smart blast design including software and new explosives, and the improvement of electronic detonators will be undertaken. The new modelling tools for blast predictions such as rock fragmentation and wall stability including optical particle size measurement developed in WP2 will be implemented and validated, also monitoring the activities linked to blasting such as loading, hauling and primary stage crushing through KPI in order to assess blasting performance.

The use of AI techniques (KTA4) linked to KTA1 to monitor and assess drill-to-mill concept and drilling planning methods will also be implemented and validated, including the implementation of dynamic image analysis to measure vibrations and the development of a new system to assess the influence of blast-induced vibrations on the structural integrity and response of buildings and other structures. H&S (KTA5) and Environmental (KTA6) technologies will also be implemented.

As mentioned, MAXAM's innovation is not to develop a new blast design software. As the reviewer has noted, several blast design software packages already exist in the market, including Maxam's Rioblast software (In fact, certain components of Rioblast were developed in the SLIM project of the Horizon 2020 program). The objective of this effort by Maxam in the Digiecoquarry project is to develop certain specific software components of Maxam's X-energy platform (which includes Rioblast). What is mentioned as innovation is the development and validation of new explosive products, applications, and performance, including a unique system patented by MAXAM to vary the explosive density instantaneously as a blasthole is being loaded with bulk explosive.

There are several blast design software packages available in the market both for mining and quarrying industry, as noted earlier (Orica – Shot Plus, Blast MAP III, JK Simblast, I-Blast, Maptek – Blastlogic, O-pitblast, Geo-Konzept, Paradigm, among others). However, they prepare the loading design using the same basic methodology, which uses a single the average density for one unique product, when using a bulk explosive, or by combining cartridges and bulk ANFO, which also considers a single density in a blast hole in the blast design process.

Regarding Rock recognition, since rock characteristics have an important influence on the drilling response, technologies based on monitoring the performance of drill rigs by measuring drill parameters (commonly known as Measurement While Drilling, MWD) should be able to assess changes in the rock mass with high resolution (Navarro 2019). Substantial research efforts aimed to correlate the MWD technology with the geological/mechanical interpretation of the rock mass (Teale, 1965; Scoble et al.,1989; Peck, 1989; Schunnesson et al., 2012; Leung and Scheding, 2015; Kahraman et al., 2016), on one side, and with the structural condition (Schunnesson, 1997; Peng et al., 2005; Tang, 2006; Ghosh et al., 2018; Navarro et al., 2019; van Eldert et al., 2020), on the other, (among others) have been reported. However, none of these methods or systems cover the combined analysis and representation of both mechanical and structural properties together. In addition, to the authors' knowledge, few of them have been applied to blast design and validated in production environments. The X-Rock model (MAXAM's technology to be implemented in Digiecoquarry) combines the hardness and the structural condition of the rock in an overall novel rock factor, that, exclusively based on drill monitoring data, can provide a blastability assessment to be used in blast design to adapt the explosive energy (density). This development will form part of RIOBLAST software.

Using a bulk explosive with only one density in any one blast design is still the common practice in the majority of the operations – and limits the flexibility of using bulk explosives with variable density. The bulk explosive is formed when a non-sensitive oxidizer is loaded into a blasthole along with additives. The oxidizer is converted into a bulk explosive when a chemical reaction between the oxidizer and additives generates gas bubbles inside the oxidizer mass (hence the term chemical gassing). This reaction takes time, and existing blasting practices require that once the oxidizer and the additives have been mixed and loaded into a blasthole, the reaction be given time to complete before stemming is added to the blasthole. This waiting time can be quite long, and the need to check each if the chemical reaction has finished correctly in each blasthole requires skill and patience. Remedying deviations is close to impossible. This is particularly demanding when the blasting is to be carried in challenging working conditions.

Another practice to convert oxidizer into explosive is by adding gas-filled microspheres to the oxidizer. While this practice eliminates the need to wait on the shot before stemming the blastholes, it significantly increases the cost of the explosive.

Companies like Orica, Dyno Nobel and ENAEX provide their solutions to adapt the energy of their emulsion products to the rock characteristics. For Orica's Solution, this is done by using different emulsion products (and different units to pump them) with a narrow density range. Dyno Nobel offers to change the emulsion density in the hole by varying the amount of gassing additives. This requires waiting time for the explosive to reach the desired density in each section of the blasthole (as per design), increasing operating time. In addition, the application of this solution is only available for pure emulsion matrix; no blended blasting agents (Emulsion + ANFO) can be used. ENAEX's solution is similar to Dyno's.

MAXAM's solution being developed under Digiecoquarry, uses a completely different explosive product called RIOFLEX, which is a watergel suspension, unlike an emulsion. RIOFLEX has several advantages versus conventional emulsion explosives due its ability to crosslink into a gel inside the blasthole. In addition, the explosive density can be varied instantaneously by using compressed air to generate the gas bubbles. This novel system has been patented by MAXAM (WO2019201851, EP 3556741). The compressed air will be supplied by an air compressor on the MEMU and mixed with the oxidizer at it is loaded into the blasthole. The mixing process would ensure that RIOFLEX would be loaded with the final desired density which could be checked on the spot. It would eliminate guesswork and waiting time. In addition, the system would allow an instantaneous change of density to a value between 0.6 g/cm3 to 1.4 g/cm3, a range unmatched by the bulk explosives used today. The system will be operated using X-truck technology. The system is being developed and implemented under the Digiecoquarry project for quarries operations (especially for smaller blasthole diameters), permitting the density and loading rate of the bulk explosive to be changed on demand.

This scheme has a number of advantages. Since a single oxidizer can then be used with different densities in a given blast, the explosive engineer would need only one product to load a blast which may require the use a range of densities and energies (The existing practice in quarries is to use several products, typically a high-density cartridge explosive at the bottom, a low density column charge of ANFO, pre-split explosives, with or without decking). Where bulk explosives are used in quarries, a bulk explosive with a single density is used in each blast, irrespective of the terrain geology.

Aside from the simplified logistics of handling and using one bulk explosive (RIOFLEX), the new technology would also give the blast designer the ability to customize each blast, and within the blast, adjust the energy and mass of explosive inside each borehole.

The X-truck technology and RIOFLEX are part of Maxam's X-energy platform. The other components of the X-Energy platform are Rioblast blast design software, X-Rock, the Blast center, Riotronic electronic detonator initiation system, and X-Logger. X-Rock will use the information from the MWD data obtained from drills to develop a detailed geological map of the blast terrain. This will be used by the Rioblast software to generate or update the blast design to be used in that terrain.

The Blast center is where all data will be stored for later distribution or retrieval. As a blast is being drilled, the X-Logger will be used to compare the work done with the blast design to detect compliance and deviations. The blast design will then update the explosive loading requirements in X-truck. The X-logger can also be used to verify the exact amount of explosives loaded in each blasthole based on the actual drill map. This scheme has the potential to predict the outcome of each blast with unprecedented accuracy using data acquisition, analysis and decision making in real time. The Blast Center will then make the results of the blast available to the data lake.

Software components are needed to be developed and added to the X-Energy platform so that they work as described. These components are X-Rock, Blast center, the ability to use of variable density bulk explosives and dynamic electronic detonator initiation timing in blast design, X-logger, and X-truck operation, Rioblast for blast design with flexible density explosives, and communication capabilities.

The wireless feature mentioned in the description of KTA1.4 of the GA refers to the wireless communication between the different components of Maxam's X-Energy system described earlier. These communications will enable the separate components of the X-Energy platform to work together in an integrated manner in real time.

Regarding electronic detonators, as the reviewer notes, there are a number of initiation systems on the market using electronic detonators, and one of them (Webgen by Orica) uses wireless detonator technology. It is not part of MAXAM's innovation in the Digiecoquarry project to develop a new wireless detonator. Maxam's effort here relates to using the existing Riotronic electronic initiation system to work as part of an integrated X-Energy platform, and make them more accessible for quarry operations, both in price and operational performance

1.1.7 KPIs for the project

The main interest for this quarry within the project is to study and control the fines production from blasting and, if possible, to increase the production of final fractions with higher prices and minimize, at the same time, the fractions with marginal prices. The main KPIs expected to be reached as a result of the technologies and improvements implemented at HANSON Valdilecha pilot site are:

- 30% reduction of the ratio of materials not suitable for aggregates production
- Target of 100% waste reused and / or recycled and / or recovered and / or used in restoration
- 5% reduction of transportation distances
- 20% reduction of generated waste
- 20% reduction of vibrations
- 20% increase in investment in geological and mining research & management

Additionally, production related KPIs to be followed in the plant are listed in Table 4.

Table 4 –HANSON Valdilecha quarry production KPIs

MEASUREMENT (input)	KPI (or output)	Description
Primary bypass flow (scale)	Tons of bypassed material (<100 mm) per blast	Stored in Hanson's plant PLC system
Current scales	Tons of each product type (per blast)	Stored in Hanson's plant PLC system
Primary crusher ammeter	kW/ton (per blast)	Stored in Hanson's plant PLC system
Availability of the primary crusher	h/blast (per blast)	Derived from ammeter log
Primary crusher throughput	tons/h (per blast)	Trucks, mass balance reconciliation

1.2 Description of HOLCIM Peschiera Borromeo-Pioltello quarry

Holcim Aggregati Calcestruzzi s.r.l. (HOLCIM) is a Holcim Group company that produces aggregates (sand and gravel) for construction and road works and for ready-mix concrete in the northern Italy market. It manages 8 quarries and 21 ready-mix concrete plants. The Company has been working in the market of aggregates and ready-mix for more than 40 years. HOLCIM is also (from more than 100 years) one of the main players in the market of Northern Italy for the cement. In terms of membership and clustering, HOLCIM is an effective member of ANEPLA (Associazione Nazionale Estrattori Produttori Lapidei e Affini) and UEPG (European Aggregates Association).

HOLCIM developed by the time a large experience in the production of selected aggregates (CE marking with certification level 2+) suitable for all applications in the construction sector (concrete, asphalt, precast, premix, etc.) in compliance with the specific regulations like UNI EN 12620, UNI EN 13043, UNI EN 13139 for the different intended uses. HOLCIM has also developed consolidated experience in the design of its quarry plants, through its centralized engineering department located in Zurich. Here all aspects related to plant safety (OH&S), production efficiency, the environment and product quality are managed internally with high standards and targets.

In order to pursue the corporate objectives of customer satisfaction and continuous improvement of company performance, to create economically and environmentally sustainable solutions and, last but not least, the development of a safe working environment, the company has obtained the following certifications: UNI EN ISO 9001 - Quality management system , UNI ISO 45001/2018 - Occupational Health and Safety Management System, ISO 14001 - Environmental management system (at group level), and Organization, Management and Control Model compliant with the requirements of Italian Legislative Decree 231/2001.

1.2.1 Overview of the plant and main products

Peschiera Borromeo-Pioltello quarry is selected for the DigiEcoQuarry pilot site and it is located in Pioltello San Bovio (Milan, northern Italy). The quarry is producing coarse aggregates in fraction of 4 mm to 32 mm (40 000 t crushed, 235 000 t non-crushed annually) and sand < 4 mm (25 000 t crushed, 158 000 t non-crushed annually). Estimated amount of mineral waste is 32000 t annually. Type of rock is alluvial deposit (Granite, quartzite, metamorphic rocks (gneiss), carbonate (rare).

Operation's start year is 1960 for the whole site, 2013 for the last permit. The provincial quarry plan duration is 10 years. For this site it is foreseen that at least 2 quarry plans covering 20 years will be implemented.

Table 5 – HOLCIM Peschiera Borromeo-Pioltello quarry annual production

Product type	Crushed natural aggregates (tons)	Non-crushed natural aggregates (tons)
4 mm < coarse aggregate < 32 mm	40 000	235 000
sand < 4 mm	25 000	158 000

Figure 4 – HOLCIM Peschiera Borromeo-Pioltello quarry

1.2.2 Material transport methods and measurement systems

From the hydrogeological point of view at the regional level, the units described above are home to the first aquifer or "water table" which, in the quarry area, is located at a depth of 3-5 meters. The main rock types of the quarry site within the alluvial deposit are granite, quartzite, metamorphic rocks (gneiss), and carbonate (rare). The bulk density is in average 1.9 - 2.0 gr/cm^3.

Extraction is done by dredging and transport into the plant by conveyor belt. The material extracted from the dredge is delivered to the process plant (crushing and screening) to produce all finished materials (sand and gravel in several granulometry) ready for sale.

Products are stored in stockpiles. Loading is done by trucks with wheel loader. The following sensors / measurement systems are already in use:

- Automatic fuel consumption measurement (for wheel-loaders)
- Level sensors (radar)
- Rotation sensors in conveyors belt
- Anti-stucking sensors (radar)
- Weigh in conveyor belt
- PLC/DCS models
- SCADA Data management
- Weighbridge truck scaling (D800 + Log on)

A detailed table of sensors and their HAC-codes is listed in Table 6. In Table 7, a list of additional sensors which are foreseen to be installed in DEQ project in order to achieve the KPIs listed in section 2.2.7.

Table 6 – Sensors currently used at HOLCIM Peschierra Borromeo-Pioltello quarry

Sensor type	HAC code
Level sensor	271-3B1
Rotation sensor	271-NA...
Rotation sensor	271-NA...
Rotation sensor	271-NA...
Anti-stucking sensor	271-NA...
Rotation sensor	271-NA1
Anti-stucking sensor	271-NA1
Rotation sensor	271-NA2
Anti-stucking sensor	271-NA2
Rotation sensor	271-NA3
Anti-stucking sensor	271-NA3
Rotation sensor	271-NA4
Rotation sensor	271-NA5
Rotation sensor	271-NA6
Rotation sensor	271-NA7
Rotation sensor	271-NA8
Rotation sensor	271-NAA
Level sensor	281-3B1
Rotation sensor	281-NA...
Rotation sensor	281-NA1
Rotation sensor	281-NA2
Anti-stucking sensor	281-NA2
Rotation sensor	281-NA3
Rotation sensor	281-NA4
Rotation sensor	281-NA6
Rotation sensor	281-NA7
Anti-stucking sensor	281-NA7
Rotation sensor	281-NA8
Rotation sensor	281-NA9
Anti-stucking sensor	281-NA9
Rotation sensor	281-NAA
Anti-stucking sensor	281-NAA
Rotation sensor	281-NAB
Rotation sensor	281-NAC
Rotation sensor	281-NAD
Rotation sensor	281-NAE
Rotation sensor	281-NAG
Weigh	271-BN1
Absorption measurement	281-VE1
Absorption measurement	281-FM1

Table 7 – Sensors to be installed at HOLCIM Peschierra Borromeo-Pioltello quarry during the DEQ project

Sensor type	HAC code
Anti skid sensor	271-NA1
Electric transducer	271-NA1
Anti skid sensor	271-NA2
Camera	271-NA2
Q-vision	271-NA2
Volumetric sensor	271-NA4
Volumetric sensor	271-NA6
Volumetric sensor	271-NA7
Volumetric sensor	271-NA8
Temperature sensor	271-SH1
Vibration sensor	271-VV1
Vibration sensor	271-VV2
Camera	271-VV2
Electric transducer	281-NA2
Volumetric sensor	281-NAB
Volumetric sensor	281-NAC
Volumetric sensor	281-NAD
Volumetric sensor	281-NAG
Vibration sensor	281-VV1
Camera	281-VV1
Vibration sensor	281-VV3
Vibration sensor	281-VV4
Pressure transducer	M31-CI1
Pressure transducer	M31-CI2
Pressure transducer	M31-CI4
Pressure transducer	M31-PE5
Volumetric sensor	281-NAE
Pump liter counter	M31-PE5
Pump liter counter	M11-PE2

1.2.3 Energy and water usage

At the Borromeo-Pioltello quarry diesel is only used in excavators and wheel loaders, and the annual diesel usage is 54 000 liters.

In the selection phases, the natural material (sand and gravel) is washed using water despite the crushing (secondary and tertiary) section is dry. The water used, at the end of the screening and washing processes of the materials, contains the finest particles (fine sands - silt) which are not retained by the sorting equipment and cyclones. These turbid waters are sent to the clarifier (static) which separates the solid-wet part from the liquid one.

The solid-wet part is sent to the settling pond while the clarified water is sent to the storage tank and used again in the washing cycle (around 90% of recycled water).

Table 8 – HOLCIM Peschiera Borromeo-Pioltello quarry annual energy use

Resource	Usage (per annum)
Diesel	54 000 l
Electricity (from distribution grid)	1 993 789 kWh
Fresh water (groundwater)	75 497 m^3 (year 2019)

1.2.4 Processing methods (crushing and screening equipment and monitoring systems in the plant)

Due the depth of the aquifer with respect to the deposit, an underwater dredge is used to extract the rock. The material extracted from the dredge is delivered (conveyors belt) to the process plant (crushing and screening) to produce all finished materials (sand and gravel in several granulometry) ready for sale.

The actual dredge is a Rohr RS 8,0/32 that is currently working on a maximum depth of 42 meters from surface. The bucket capacity is 8 cubic meters, and the dredge is operating with double shift (4 people) for a total of 15 working hours daily. The average dredge production is currently 2.200 – 2.300 t/day with an average of 11-15 bucket cycle/hour.

The dredge is equipped with 2 electrical engines 160kW each (for the winch) and the excavation is both automatic and manual and is operated through PLC.

There are sensors that provides:

- Rotation measurement of the machine drum that is length in meters (excavation depth)
- Numbers of bucket cycles (that is nominal ton/hour)
- Time opening – closure of the bucket
- Amperemeter on the winch engines

There is no connection (Lan or Wi-Fi) from the dredge to the quarry plant, so all the data are manually reported day by day to the management system of the quarry. The optimal bucket cycle is 2 minutes at 24 meters depth. The current conveyors speed is 2,2 meters/second for a maximum nominal capacity of 300 ton/hour.

The produced aggregates are moved by conveyor belts to the plant over a distance of approximately 850 m. In the selection phases, the natural material (sand and gravel) is washed using water, although the secondary and tertiary crushing sections operate dry.

Before the main stockpile of the plant is in place a rotation pre-screen that discard +250 mm fraction (191-VR1). Starting from the stockpile there are 3 drawer extractors that allows at full capacity of 300 t/h. (271-AC1/2/3)

The material after a weigh reaches the first screen Metso Ellivar (271-VV1) (triple deck 2100*6000) from here the natural material (4/24 mm) goes to horizontal screen Cedarapid 271-VV2 (triple deck 1930*6000) and the size 24/120 mm goes to silos 271-3B1 and the cone crusher Nordberg HP200 281-VE1.

A single Nordberg (HP200) cone crusher, supplied by Metso, is used for secondary crushing. The plant downstream from that is set up with maximum flexibility to produce different proportions of the various size fractions, since demand for the various fractions fluctuates seasonally. Splitters at various points throughout the circuit permit the routing of any fraction of any stream to be either taken as product or to proceed for further processing.

The secondary crusher product proceeds to a Metso TS screen 281-VV1 (3-deck 1530*5490) producing (a) an over-size of nominally 24/60mm which can partly or in whole be recycled to the secondary crusher, (b) nominally -14/22 mm fraction, (c) nominally 4/14 mm fraction and (d) nominally 0/4 mm under-size. Fractions (b) and (c) can wholly or in part proceed to either stockpiling or further re-sizing to a tertiary crushing VSI Barmac B7150SE 281-FM1 and screening to a second Metso TS screen 281-VV4 (3-deck 1530*5490).

The sand production (natural 0/4 0/8 or crushed 0/4) is guaranteed to 4 hydrocyclons MS M31-CI1/2/3/4 (2 diameter 650 for naturals and 2 diameter 750 for crushing). The water recycling is managed by a Tecnoidea static decanter M31-3W1 with an automatic doser for flocculant.

1.2.5 Development targets in DigiEcoQuarry

- KTA2.2 Models for crushing and screening optimization (REFERENCE PILOT)
- KTA3.1 Devices for automation of treatment plants and storage facilities (REFERENCE PILOT)
- KTA3.3 Mobile equipment and quarry geological deposit digitalization & real time modeling
- KTA5.1 H&S recognition system
- KTA6 Environmental impact minimisation

1.2.6 Summary of technologies to be developed

Peschiera Borromeo-Pioltello quarry will lead to the implementation of the Key Technology KTA2.2 (Models for crushing and screening optimization), and KTA3.1 (Devices for automation of treatment plants). No position sensors (GPS) are nowadays installed in the dredge and for the deposit (rock characterization, etc), the water table and bathymetric survey data are collected by campaigns. The technologies to be developed in this pilot site are mainly connected with the optimization of the crushing, screening and washing processes related to the production of sand and gravel (alluvial deposit) as well the project aims to increase the efficiency of the aggregates plant with the reduction of electrical consumption and fresh water per t/h produced (gross). To achieve this specific goals the project counts on the plant site with the right management of the SCADA system combined with all the sensors positioned in the several machines in the plant. The DEQ project foreseen for the Pioltello quarry the installation of new sensors and devices focused on the project's KPI (see specific tab).

Mintek will develop a digital twin model that will make use of Microsoft Excel for data capture, analysis, pre-modelling and storage, as well as a robust flowsheet simulator (IDEAS™) which will communicate with Microsoft Excel via a macros written in the Visual Basic Analysis (VBA) programming language. The flowsheet model will simulate the section of the plant consisting of the first screen (Metso Ellivar: 271-VV1), silo (271-3B1), Nordberg cone crusher (HP200) and the Metso TS screen (281-VV1) which receives the crusher product. IDEAS™ by ANDRITZ Inc. is considered a leading process simulator in the fields of mineral processing, oil-sand operations, pulp and paper, potash operations and the power industry. It is especially suited for use in the digital twinning of mineral processes (related to the aggregate industry in this case) due to its extensive library of icon-based "objects" that typically have a one-to-one correspondence with actual processing equipment (ANDRITZ, 2023). Other simulations software packages such as Aspen Plus and CADSIM Plus typically specialize in aqueous chemical processes while open-source software packages like Cape Open Flowsheet Simulator (COCO) do not offer the same number of features and post-installation support as IDEAS™ does.

Phenomenological, numerical or empirical models are used for the simulation of the screens. Empirical models are the most practical and feasible based on computational time and efficiency. These models include the Allis-Chalmers method proposed by Allis-Chalmers (1953), PKM proposed by King (2001) and the Karra model proposed by Karra (1979). They are typically based on aspects related to the screen's expected throughput capacity for a predefined standard feed material, its transmission efficiency related to the amount of undersize material that reports to the undersize stream and its classification function which looks at the probability that an individual particle will enter the oversize stream. Though the Karra model is currently the most widely applied and is integrated into the Screen "object" in IDEAS™, Mintek will consider different empirical screening models and classification curves during the model calibration process.

Models used to simulate cone crushers are grouped as either population balance, empirical or data-driven. Discrete element method (DEM) modelling is a numerical technique that is also used to track the path of particles in a crusher based on the integration of its laws of motion. However, DEM methods are computationally expensive and have been scarcely applied in the design and control of cone crushers. Data driven models are still relatively new, requiring large amounts of data for accurate prediction and the literature surrounding them is relatively scarce (Yamashita et al., 2021). Most empirical models are very situation specific and cannot be readily applied to other crusher models. Whiten (1972) derived what is arguably the most well-known cone crusher model based on population balance equations which utilizes breakage and classification matrices. These matrices are represented as functions. The breakage function defines the fraction of particles within a top particle size fraction that reports to a lower particle size fraction during fragmentation or breakage. The classification function gives the probability of particles leaving the crushing zone of a crusher which is dependent on their particle size. Breakage function parameters can be obtained via laboratory test work while classification function parameters are calculated based on certain operational variables (Yamashita et al., 2021).

The Crusher "object" in IDEAS™ requires the bond work index and output PSD for a particular crusher feed. Mintek will conduct laboratory scale single particle breakage tests on samples of the crusher feed material from the Holcim plant to derive the breakage function parameters. This, combined with PSD data from the relevant process streams in the plant will be used to calibrate the classification function. Once the models are calibrated, the digital twin will then be used to optimize the crusher operation based on KPI targets for the project.

We briefly consider historical work and the state-of-the-art applicable to the optimization of the crusher. Early work at Nordburg starting in the late 1970s (O'Bryan, 1987) developed a simulation package and showed how users could analyse different scenarios during crusher design and operation. Huang et al. (2007) developed a cone crusher simulation to test new internal geometries before testing the optimum design on a physical crusher. Scenarios were selected manually for analysis in the simulation. Gawenda and Saramak (2022) followed the factorial experiments methodology in testing different crusher speeds and gap settings for an impact crusher. Data was collected manually, and the optimisation campaign does not represent a continuous adaptation to changing ore properties and crusher behaviour. Santos et al. (2020) demonstrated an iterative local search method for optimising the efficiency of a large three-stage crushing circuit consisting of 15 crushers. The goal was to improve performance by changing the feed rate and number of active crushers. The configuration of individual crushers, e.g. closed side setting, was not affected. Typical crushing circuits in quarries are not large enough to benefit from this methodology.

In principle, the state-of-the-art offline optimisation approaches have not advanced beyond testing a fixed set of crushing circuit configurations in a simulation or a physical optimisation campaign, followed by implementing the optimum configuration thus located. Repeated optimisation is done rarely, if at all. In contrast, real-time optimisation is well-developed for other sections of the comminution circuit (Coetzee and Ramonotsi, 2016; Steyn and Sandrock, 2013). This discrepancy results partly from the lack of automation in most crushing circuits. Continuous optimisation approaches exist (Hulthén and Evertsson, 2011, 2009; Yamashita et al., 2021) but rely on a level of automation within the crusher unavailable at many quarries, including this site. For example, the crusher should support a variable speed drive and allow automatic changes to its closed-side setting.

A key observation is that increased computing power, cloud computing and widespread access to the Internet allow the manual optimisation approach outlined above to be partially automated. Particle size distribution sensors will be installed in the crushing circuit to replace the manual sieving of samples. The Industrial Internet of Things enables automatically collecting these and other measurements, e.g. power consumption and throughput, in the cloud, where it becomes possible to recalibrate the model of the crushing circuit, or digital twin, in real-time. This online digital twin allows both manual what-if analyses, similar to Gawenda and Saramak (2022), and the automatic generation of optimal configurations using AI, e.g. reinforcement learning (Shipman, 2021). Using other AI algorithms for fault detection and performance analysis is gaining interest in minerals processing but has yet to be used in crushing circuits (McCoy and Auret, 2019; Wakefield et al., 2018). This project includes investigating whether these methods can benefit crushing circuits in quarries.

It is worth noting that the focus here is on doing more with the available equipment and a modest investment in additional equipment, thus replacing the crusher has not been considered.

In detail the main efforts will be focused on automation and control of treatment plant (KTA 3.1 and KTA 2.2). This aims to reduce noise (10%), decrease of energy (20%), increase of efficiency (10%) reduction of primary fresh water (-5%). PSD calibrated sensors (KTA2.2) will be installed at HOLCIMS's pilot and crushing power/current measurement and signals will be made available. The required hardware and SW for collecting the PSD, power/current, and signals and interfacing SW will be relocated to the pilot site. Internet communication will be established between the (on-site) pilot-LCSI and the (remote) MINTEK-LCSI and between the pilot-LCSI and the central database at the pilot site. Once the system is 'live' with signals from the pilot site, communication between the two LCSI's and the central database of the pilot-site will be tested. Thus, the Digital- Twin/ML optimiser located at Mintek will provide remote on-line assistance to the pilot site.

Also, new sensors and cameras will be installed on the processing line (screens, crushers, silos, conveyor belts and weighing system) as well as on the cyclone line to achieve the complete automation for validating KTA3.1. The expected outputs will be: an improved efficiency of the plant measured in terms of energy (kW/t produced material in) (yield increase, reduction of energy consumption, reduction of water consumption (mc/ t produced material in), etc.) and improved speed control, level control and anti-heeling of the conveyor belts. Additionally, the water management system will be controlled by means of turbid water control with hydrometer, counter-litres, pumps, and discharge quantity control. The screens for natural and crushed material will also be tested combined with the cyclones group to measure operation parameters but also dBA noises, vibrations and lubricating oil temperature.

A new power center on the main electrical cabin combined with the sensors and SW for system management (KTA3), capable to measure Tn/h, kW/h, µg/Nmc, dBA noises, vibrations, roller bearing temperature will be implemented. Due to the conditions of the quarry, underwater excavation (dredge + conveyors) will be monitored as well as the control of production and scheduled maintenance in terms of kW/h, cost/Tn and operating hours. Moreover, the management of the conveyor belts with weighing system and volumetric sensors, sensors and cameras to control the internal transport and send the data to the IQS and new extractors (storage / raw material tunnel) with also with sensors, cameras and management and control system (to measure Tn/h, kW/h, control speed) will be implemented.

Also a data communication system between weighing bridge/cabin and wheel loader for loading and selling finished products will be undertaken to ensure product, quality and quantity. H&S tools will be implemented to measure the H&S parameters (LTI, total frequency index) (via KTA3.3 and 5.1). Moreover, Environmental (KTA6) technologies will also be implemented.

With ARCO's continuous weighing system with an encoder, it is expected to achieve more than 10% precision than with current weighing systems, adjusting consumption. All this is achieved due to the fact that with this new system, the measurement pulses go from 8 to 1024. In addition to the reduction of emissions due to greater control of the load.

With the technologies to be deployed at the HOLCIM's site, Ma-estro will monitor and reduce the amount of electricity used per tonne of material produced. Besides, a further aim of the project is to measure the amount of water used and recycled.

Achieving these goals will be done with an innovative approach to the problem aimed at optimising the entire production process at the HOLCIM site. To do this, we will not focus on the individual machine but see each machine as a component of the entire production process. This goal is realistic because the typical approach is to make settings on the individual machine, not to optimise the entire production process.

1.2.7 KPIs for the project

The aim of the project is to manage the main KPIs to reach the target of noise reduction (10%), decrease of energy (20%), increase of efficiency (10%) reduction of primary and recycled fresh water (5%). Table 9 outlines the KPIs, their thresholds and their effect on energy usage, water usage, noise, and efficiency of the plant.

Table 9 – HOLCIM Peschiera Borromeo-Pioltello quarry KPIs

KPI	Unit	Threshold	Energy (ton processed)	Water (ton processed)	Noise	Efficiency
Processed aggregates	t/h	290-310	X			X
Salable aggregates	t/h	270-290				X
Production rate index	%	90%	X			X
REE	%, manual	85%				X
Processing plant energy consumption	kWh/t		X			X
Processing plant reactive energy	Cos phi	0.90	X			X
Fresh water	Litre, mc, %	140 l/t		X		
Recycling water	Liter, mc, %	90%		X		
Noise measurement plant	DbA, campaign	80			X	

1.3 Description of CRONENBERGER S.I. Mammendorf quarry

Cronenberger Steinindustrie Franz Triches GmbH & Co.KG (CSI) is a subsidiary of Pescher Beteiligungen GmbH & Co.KG, which is a fifth-generation family business that runs quarries in Germany and Nigeria for 108 years. Main products in all quarries have been aggregates for road construction (asphalt, concrete) with special focus on high quality aggregates used in top layers of roads, railroad ballast, armourstones for waterway construction and materials for production of concrete precast parts such as railway sleepers. Currently the group employs 150 people in three quarries in Germany and one recycling plant, the production is about 3 million t/year.

Since 1998, CSI operates Mammendorf quarry (Bavaria, northern Germany) that is in Germany's most northern hard rock formation and extracts and processes on average 1.2 million t/pear year of a volcanic hard rock, Andesite. Operation's end year (according to permit) is 2040. Quarrying legislation in the country is the Mining law and environmental/pollution control law. As the site has been growing along the years, different legislations apply to it because quarries' legislation has been changing during the years.

CSI is a member of VERO association (advisory board), MIRO Gesteinsverband (member of several expert groups), Deutscher Asphalt Verband, VSVI-Vereinigung der Straßenbau- und Verkehrsingenieure, Baustoffüberwachungsverein NRW, Hessen, Rheinland-Pfalz and International Chamber of Commerce (member of expert group industry and environment). It is also member and participant in expert group Forschungsgesellschaft Straßen und Verkehrswesen. CSI takes part in a platform to share knowledge, projects for energy efficiency and CO2 reduction.

1.3.1 Overview of the plant and main products

Figure 5– Aerial view of the Cronenberger Mammendorf quarry

Table 10 shows the natural aggregates produced. The production measurement is performed by a combination of weight-scale data (on mobile machinery, on conveyer belts, outbound weight-bridge), and cycle-numbers. For extraction of the rock about 0.6 million t/per year of gravel and sand material must be removed which yields to an overall production of on average 1.8 million t/per year. The geology of the deposit presents different layers of materials of different geological origin and with different technical properties. There are up to 90 stockpiles of different products. Products are sold in all northern Germany, where the quarry is a leading market player.

Table 10 – Annual production at the Cronenberger Mammendorf quarry

Product	Annual production (tons)
Armourstone	10 000
Railway Ballast	50 000
Coarse aggregate (< 32 mm)	70 000
Aggregate (3/32 mm)	950 000
Sand (< 2 mm)	160 000
Filler (< 0.0363 mm)	10 000

1.3.2 Material transport methods and measurement systems

The rock is mined by drilling and blasting. For processing, the material is moved by several excavators, quarry trucks, trucks, wheel loaders and other mobile machinery. A list of mobile machinery deployed at the quarry is presented in Table 11. Additional dumpers with personnel are rented to work on special jobs for example removal of overburden, production of special products with aggregate storage by stockpiles and by silos. Currently, the measurement systems related to material transportation at the site are:

- Geoposition:
  - Some mobile machines are fitted with geo position in their OEM (original equipment manufacturer) online systems. Often the on board-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. Table 12 shows the fuel consumption per year

Table 11 – Mobile machinery deployed at the Cronenberger Mammendorf quarry

Machine type	Model
Excavator	CAT 374 FL
	2x CAT 352 F
	CAT 329 DLN
	CAT M318 D
Wheel loader	3x CAT 872 M XE
	Komatsu WA 475
	Bobcat S 70
	Hitachi ZW 75
	Merlo 40.17
Truck	Iveco Water Truck
	MAN Road Cleaning Truck
Articulated truck	2x CAT 775 G
	CAT 775 D
	Komatsu HD 605-7
	2x Komatsu HD 605-6
Bulldozer	CAT D6 XE

1.3.3 Energy and water usage

The mobile machinery at the site consumes 850 thousand litres of diesel per year. The treatment plant runs with electrical energy from the distribution grid, and the energy consumption of different functions is tracked. CSI currently installs an energy measurement system by Schneider Electric. It comprises of 25 sensors that are installed in the stationary production plant, a server that sends the data to a cloud server and an online platform system, that can be accessed via a website, where the data, aggregated data, KPIs etc., can be customized to the individual needs. Fuel is mostly used by Jeeps, utilized for personnel transportation at the quarry. A breakdown of annual energy consumption is presented below in Table 12.

Table 12 – Annual resource consumption at the Cronenberger Mammendorf quarry

Resource	Usage (per annum)
Diesel	850 000 l
Fuel	2 500 l
Electricity (from distribution grid, total)	3 100 000 kWh
Electricity consumed in crushing	1 200 000 kWh
Electricity consumed in screening	260 000 kWh
Electricity consumed in conveyance	660 000 kWh

Furthermore, the number of consumables used at the quarry is tracked. Yearly, 1 ton of screen meshes, 0.5 ton of rollers and 5 tons of equipment wear protection elements are used at the quarry.

1.3.4 Development targets in DigiEcoQuarry

MAIN CHALLENGE / IMPROVEMENT: Resource efficiency, Production efficiency, Energy efficiency, Efficient

deployment of mobile equipment

- KTA3.3: Mobile equipment digitalization, real time modelling & data (REFERENCE PILOT)
- KTA4.1 BIM
- KTA4.2 AI Algorithms
- KTA4.3 IQS
- KTA6.1 Environmental simulation platform
- KSA7.1 Public acceptance
- KSA8.1 Communication with policy makers

1.3.5 Summary of technologies to be developed

Due to increasing energy prices (CO^2 taxation, gas scarcity) and very high energy taxation (energy transition of Germany) **energy efficiency** is one main focus. Membership/Participant in an official "Energy efficiency network" deployed by the German government. Main goal within DEQ: Diesel consumption optimization.

As the quarry grows, the distances for internal material transport increase, which will lead to increasing fuel consumption.

- Own energy measurement sensors installed
- Highest efficiency improvement opportunities are expected in the deployment/usage of mobile machinery
- Energy efficiency improvements concerning the stationary installations have been already realized with various major projects during the past 10 years (improving ventilation technologies for dust extraction, improvement of dewatering system, change of electrical engines, installation of frequency inverters, removal of bottle necks in the production process etc.)
- The main priority is efficiency increase in usage of mobile equipment. That is expected to be achieved by the usage/development of a telematic system collecting and processing all relevant data concerning the usage of mobile machinery

Specific requirements concerning such telematics system/ the platform are:

- The system must be able to compare mobile equipment from different machinery suppliers in one common report and analysis system
- The system must be capable of processing internal machine data and external data like GPS, tire pressure, fuel data, weight scale data etc.
- The system must be easily accessible, user friendly and freely configurable (i.e. concerning KPIs)
- The system needs to allow a target – actual value comparison
- The system must not show only statistics (averages, etc.) but also individual values (on daily or hourly basis) for deep analysis
- The system must allow a quick overview on the last day, week, month, other months, last year, last years, etc.
- The system must allow for analysis of machinery pairs (i.e. excavator and two quarry trucks)

- The system must allow to individually configure limit values for warnings, target values for comparison and geo-fences
- The system must allow comparison between mobile equipment of different sites
- The system needs to allow the input/change of the underlying site map / site 3D model by the user, so that the quickly changing environment in the extraction sites is always correctly displayed
- The system must allow data export to Excel for further analysis
- The system must be able to generate automatic reports
- The system needs to be “open” to integrate data from other areas (i.e. drilling, blasting, plant, quality control)
- The system must be an affordable solution

With this, following goals could be achieved:

- Fuel consumption per ton reduction
- Tyre life-cycle management (reduction of consumption and costs)
- Environmental impact reduction by reducing consumptions, emissions of GHG, waste, etc..
- Increased effectiveness and productivity of the operation (i.e. reduction of idle time)
- Breakdowns reduction
- Reduction of operation errors by optimized operational planning
- Reduction of administrative effort

The challenges are:

- Very few internal machinery data is freely/easily accessible, since each manufacturer seeks to develop its own “closed shop” system
- Some installed after-market sensors legally endanger the machine guaranty
- Need for expensive GPS reference station for the site, because of low GPS-coverage in some parts of the quarry
- Costs of data transfer
- Information going to the right user of the information / machine.
- Precise and real-time GPS position to define best paths (GPS technology and data transfer).
- Combination of GPS position with internal roads’ transversal profile (at least for main roads).
- Consumption information according to the driving modes (Power, ECO etc.) of the machines.
- No “space” for more specific real-time information for the driver or the machine, since the displayed information is already large (“normal” machinery displays, video/radar, weight-scale information, tire-pressure monitoring system and more).

This pilot will focus on the validation of KTA3.3 “mobile equipment digitalization” (including GPS, RTK, acceleration and data logger on the existing mobile-equipment like wheel loaders, dump-trucks and excavators of different brands/manufacturers). Once the hardware is installed, the data of the existing sensors of the machines will be attempted to be read out via the machine’s CAN-Bus: fuel-consumption, working-hours, technical alerts, rpm, etc. and stored in a data logger, which will also collect data of added equipment like GPS, weight scales and tire-pressure monitoring systems, etc.

All the collected data will be transferred from the data logger to a cloud server via mobile network or Wi-Fi. The processed, aggregated and linked data will be shown in an online fleet-management system. Performance and interaction of the mobile equipment will be shown in real-time, including KPIs that can individually be configured to the special needs of the individual quarry operation. These include fuel consumption minimization (and improved CO^2 efficiency), improved efficiency of the equipment, minimization of idle- and downtime, improvement of the internal road-system and maintenance interval, improved H&S measures, etc.. CSI participation will mainly be testing of the needed hardware in a rough quarry environment, testing and optimizing the data transfer between machinery and between data logger and cloud server and testing the software from the perspective of a small-medium sized quarry operation. Thereby collected data will be validated and KPIs will be developed that help to achieve the declared goals.

1.3.6 KPIs for the project

Increasing the energy efficiency is the main target of the project for CSI. The KPIs expected in this project are:

- 5% reduction in transportation distances
- 5% reduction on fuel consumption
- 5% reduction of CO2 emissions
- 5% reduction of downtime and repairs

1.4 Description of CIMPOR Alenquer quarry

AGREPOR is a Portuguese aggregates producer with 10 active quarries and owned by the major Portuguese cement producer. Furthermore, CIMPOR is member of ANIET (National Association of Extractive and Manufacturing Industry).

1.4.1 Overview of the plant and main products

Figure 6 – Aerial view of the CIMPOR Alenquer quarry

AGREPOR has a wide variety of quarries (granite, limestone, dolomite and gypsum) and supplies a wide variety of public and private customers that operate for instance in public works, RMC, fertilizers, lime production, cement, concrete, ballast, mortar, etc. AGREPOR will pilot and validate the proposal in one of its limestone quarries located in Alenquer (Lisbon district, central region of Portugal).

Type of rock: Limestone

Crushed natural aggregates are the main product. The site supplies a Cement plant nearby with all in materials. It also provides 3 concrete plants and 1 mortar plant. The quarry has started operating in 2007. The main products produced are presented below in Table 13.

Table 13 – CIMPOR Alenquer production

Product type	Information
Armourstone	Crack and Rockfill
Coarse aggregate > 32 mm	Gravel 3
4 mm < Coarse aggregate < 32 mm	Berry rice, Gravel 1, Gravel 2
Sand < 4 mm	Stone dust
All in 0+ mm	Tout venant, rich limestone, debris

1.4.2 Material transport methods and measurement systems

For transportation, there are five wheel loaders, and six trucks manufactured by different producers. A list of mobile machinery is presented in Table 14. The site gathers of data from automatic truck scaling (Cachapuz SLV) and an automatic fuel consumption measurement. KoboToolbox is an online tool that each worker fills in at the end of the day. It reflects, among other things, daily consumption. For mobile equipment this sheet is analysed monthly. Additionally the site, a track and trace system for explosives and detonators is used.

Table 14 – Mobile machinery deployed at the CIMPOR Alenquer quarry

Machine type	Model
Wheel loader	Volvo L350F
	Volvo L150H
	2x Volvo L150ECAT 988G
Truck	Komatsu HD465-7
	4x Komatsu HD465-5
	Euclid R32

1.4.3 Energy and water usage

Table 15 lists the current situation in terms of resource usage at the quarry.

Table 15– Annual resource usage at the CIMPOR Alenquer quarry

Resource	Usage (per annum)
Diesel	461 527 l
Fuel	11 262 l
Electricity (from distribution grid, total)	1 511 675 kWh
Water consumption (fresh water)	12 624 l

1.4.4 Development targets in DigiEcoQuarry

- KTA3.1 Packaging optimization, Automation Software + electrical connections for storage optimization and improvement of OOE (REFERENCE PILOT FOR STORAGE)
- KTA3.2 Monitoring sensors and analysis tool for mobile machinery for internal and external transport optimization (REFERENCE PILOT FOR EXTERNAL TRANSPORT)
- KTA4.1 BIM
- KTA4.2 AI Algorithms
- KTA4.3 IQS
- KTA6.1 Environmental simulation platform
- KSA7.1 Public acceptance
- KSA8.1 Communication with policy makers

1.4.5 Summary of technologies to be developed

In CIMPOR's site, the autonomous and intelligent system for aggregates transportation from crushing to stock, storage, and external transport traceability (KTA3.1&3.2) will be implemented with the focus on rationalising energy consumption and using equipment. Main areas monitored will be levels of the silos, analysis of the stock zone for prioritisation on transport, remote and autonomous interpretation of storage locations.

The installation of technologies that enable an autonomous management will allow prioritising the aggregates to be transported, optimising routes, transport speed and deposition sites with all security safeguards, validating and demonstrating these DIGIECOQUARRY solutions. For external transport, the validation of the technologies that enable full traceability from the quarry to the customer will be demonstrated by ensuring route optimisation in terms of the best possible route that minimises transportation time and fuel consumption, estimated time of arrival (ETA) and communication to customer and quarry (dispatch), sharing of inter-fleet information to adjust the travel speed and to guarantee just-in-time in congested unloading sites. Other aspects that will be validated in terms of storage to external transport connection will be the correct identification of the aggregate to be loaded, silo discharge control, correct truck positioning without spilling and cargo viability and communication to driver. H&S (KTA5) and Environmental (KTA6) technologies will also be implemented.

1.4.6 KPIs for the project

The KPIs targeted at CIMPOR Alenquer quarry for the project are:

- 10% improvement in storage OOE
- 5% reduction in internal transportation distances
- 20% reduction in external transportation distances
- 5-20% reduction in fuel consumption

1.5 Description of VICAT Fenouillet plant

The VICAT Group is a cement group, based in France with a turnover of 2,6 billion euros. Present in 13 countries, it employs nearly 9000 people.

1.5.1 Overview of the plant and main products

Figure 7 – Aerial view of the VICAT Fenouillet site

The site of Fenouillet is a real urban quarry. This a 46 000m2 site with urban neighbours such as Decathlon, Mc Donald, King Jouet, etc. It stands in the heart of Toulouse area which counts 1 million inhabitants. This quarry has the particularity of not having any extraction site linked. It only works by recovering raw materials issued from local earthworks. The products are used to supply the concrete plant installed on the same site and to supply customers. This site is at the forefront of the circular economy in the field of building and public works. It is indeed very rare to find such a large recycling platform in the immediate vicinity of a large urban centre, producing very upgraded products such as aggregates for concrete. This saves on raw materials, transport to evacuate C&D wastes and transport again to bring back aggregates. Type of rock: Alluvial soils (the company receives earthworks soils coming from various job sites all around the site) for treatment.

Operation's start year is 1970 and no end foreseeable as there is no excavation, only recycling. Due to the urban location of the site, environmental requirements need to be fulfilled for the operation:

Requirements for treatment emissions:

- The noise limit admitted is 70dB at the property line, special attention must be paid to the noise level of the crusher
- Concerning dust, the limit admitted is 500mg / m² / day, a misting system has to be associated with the machines
- Engines need to be complying with the STAGE standard in Europe 3.5g / kWh CO and 0.4g / kWh for NOx

This site has three types of inflows:

- Aggregates coming from another quarry of the company to be sold on site or to be used to fill the ready-mix concrete plant
- Construction and demolition waste material, that other companies pay them to take it to the site, where they are treated and used as backfilling within Granulats Vicat group e.g. C&D waste (concrete, tiles, brick, asphalt)
- Excavated alluvial soils.

Soils are brought from outside earthworks jobsites, for example aggregates coming from Carbonne site (60 km). Crushing campaigns are carried out according to the receipt of deconstruction materials. Around 2 campaigns per year are carried out for a volume of around 15,000 t / year. This tonnage may increase within the next few years. Each crushing campaign lasts between 15 to 21 days.

The annual production is presented in Table 16.

Table 16 – VICAT Fenouillet annual production

Product type	Annual production
Non-crushed	
Coarse aggregate > 32 mm	7 993 t
4 mm < Coarse aggregate < 32 mm	14 105 t
Sand < 4 mm	11 754 t
Crushed	
All in 0- mm	13 164 t
Recycled	
All in 0- mm	21 417 t

1.5.2 Energy and water usage

Resources used at VICAT Fenouillet plant are listed in Table 17. Water for the site is primarily abstracted from surface water. A system of three settling tanks is utilized to enable recycling of water at the site. Roughly 30% of the energy consumption can be attributed to a local batching plant.

Table 17 – VICAT Fenouillet annual resource usage

Resource	Usage (per annum)
Fuel	29 878 l
Electricity (from distribution grid, total)	123 573 kWh
Water consumption (total)	194 730 m^3
Recycled water	84 967 m^3
Aggregate and equipment washing	182 472 m^3
Irrigation of runways (dust prevention)	12 258 m^3

1.5.3 Processing methods (crushing and screening equipment and monitoring systems in the plant)

Primary crushing, and mobile crushing plant rented when needed for crushing of recycling waste. Typical crushing and screening equipment used at site are listed in Table 18.

Table 18 – VICAT Fenouillet site equipment

Machine type	Model
Crusher	SANDVIK CFBK 11/50 100 kW
	SANDVIK CFBK 15-24 37 kW
	Mobile crusher (rented when needed)
Feeders	5 kW feeder
Screens	CR1 DRAGON VP4 15 kWA
	CC3 BERGEAUD 1330 7.5 kW
	MS 8'20"
Other equipment	Hydrocyclones (MS 8x20)
	Lubricators for crusher CFBK 11/50
	Storage and flocculation containers
	Pump (Rovatti 250 m3/h, 45 kW)
	Pump (CANTONI MILANO 250 m3/h, 37 kW, backup)
	Magnet for removing metals from material

1.5.4 Development targets in DigiEcoQuarry

- KTA2.1 Innovative mobile crusher (REFERENCE PILOT)
- 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: CHALMERS
- KSA7.1 Public acceptance: ZABALA (REFERENCE PILOT)
- KSA8.1 Communication with policy makers.

1.5.5 Summary of technologies to be developed

This quarry will be the reference for social acceptance (KSA7,). The new mobile crusher (KTA2.1) will have implemented and validated in VICAT's pilot. This mobile crusher will be first noise encapsulated horizontal impact crusher with electrical powertrain. Lowering the noise levels together with additional dust suppression system enables the crushing in urban environment, since the environmental impacts by noise and dust are significantly reduced. The technologies for noise encapsulation, dust suppression as well as electrification will be based on the latest R&D activities and scientific findings available.

Innovation in control of the new mobile crusher in combination with a new electrical powertrain improve the energy-efficiency while simultaneously increasing the performance of the machine. This also leads to reduction in emissions per ton of aggregates produced. Furthermore, electrical components are utilized in an innovative way, allowing a single component to perform multiple tasks in the powertrain – tasks, which are conventionally performed by more than one component. Overall, technologies new to mobile crushers are utilized to create a more efficient, environmentally friendlier machine without compromising performance.

In 2018, Lajunen et al. presented an overview of powertrain electrification in non-road mobile machines (Lajunen et al. 2018). While the overview was made five years ago, status of electrification of non-road machinery has not changed significantly. Lajunen et al. state that in non-road mobile machines "most of the work systems, such as boom or bucket operations, are powered by hydraulic cylinders that are difficult to replace by any corresponding electric system." As a result, non-road mobile machines, including mobile crushers, are typically powered with diesel-hydraulic powertrains. While electrical mobile crushers have been on the market for over a decade, the new machine to be developed will take a leap in the rate of electrification and demonstrate innovation in its new features.

Complete automation (KTA3.1) within the quarry will be validated by the installation of sensors and cameras (feed hopper, screens, crusher, conveyor belts, water treatment) for control and optimisation of the efficiency rate in the raw material. Control of energy consumption and weighting, dust and noise emissions of processing is preferred. There is currently no digital system installed on site for the C&D waste crushing.

In addition, a new log-washer combined with a new double sand treatment (cyclone group) will be implemented to measure the % of clay accepted in the raw material, and % of recovery. Regarding water treatment, a washing plant thickener will be implemented in order to improve water recycling. H&S (KTA5) and Environmental (KTA6) technologies will also be implemented.

1.5.6 KPIs for the project

The KPI targets at VICAT Fernouillet site are:

- 50% increase of social interaction index
- 100% for identification of stakeholders
- 50% increase in level of inclusion and effectiveness of dialogues with stakeholders
- 20% reduction in energy intake
- 20% reduction in emissions directly linked to KTA3.1 Automation Software + electrical connections and Production System
- 20% reduction of accidents due to KTA5.1 H&S recognition system

2 References

The contents of this deliverable are mostly based on **site visit reports** made in DigiEcoQuarry. These reports are available in the DigiEcoQuarry Teams channel. Additional comments and remarks were collected from DigiEcoQuarry participants via email.

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