Digital 4 Sustainability
Skills for Europe's Twin Transition

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Urgent Up-Skilling

Introduction to Digital Twins as a tool to promote Sustainability.

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Urgent Up-Skilling

This course is provided by:

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Agenda

1. Introduction and overview on the project Digital4Sustainability
2. Digital Sustainability in Industry - Roberto Moreno
3. Digital Twins and Model Based System Engineering (MBSE) - Iván Pena
4. Use case 1: Digital Twins for a Water Treatment Plant- Carlos Rodríguez
5. Use Case 2; Digital Twin for additive manufacturing of mortars - Carlos Real
6. Q&A and Contest Winner
7. Evaluation and closing

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Meet the speaker

Introduction and Overview of the project D4S

Dr. María Dolores Cima Cabal

Academic Director, UNIR

https://www.linkedin.com/in/dolores-cima-15046633/

Meet the speaker

Digitalización y Sostenibilidad en la Industria

Dr. Roberto Moreno García

Profesor Asociado, UNIR

Meet the speaker

Gemelos Digitales y Model Based System Engineering

Dr. Iván Pena

Coordinador Académico UNIR

Meet the speaker

Gemelos Digitales en una planta de tratamiento de agua

Carlos Rodríguez, Especialista en GD

Ayesa Ingeniería y Arquitectura

www.linkedin.com/in/carlosrdrzalns

Meet the speaker

Gemelo Digital para la Fabricación Aditiva de Morteros

Carlos Real Gutiérrez

PDI Universidad de Cantabria

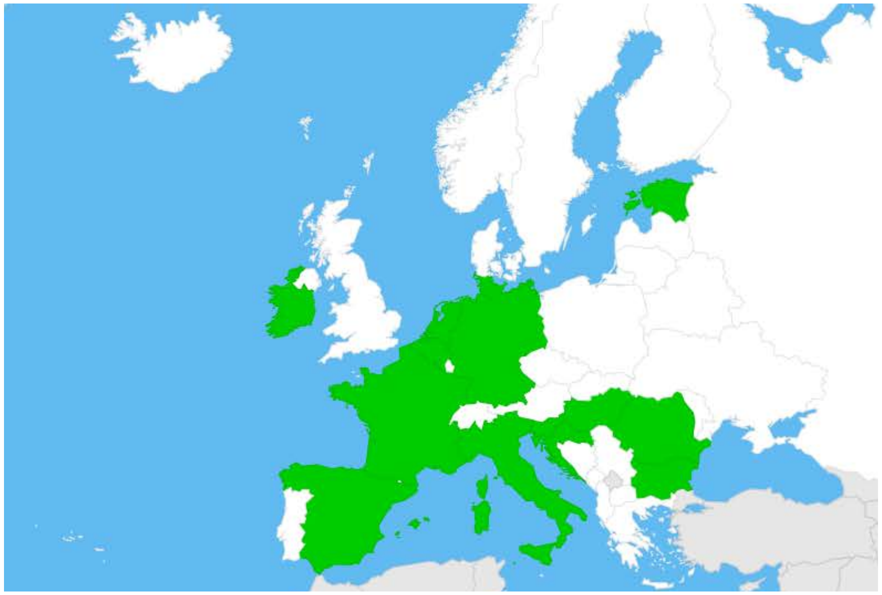
Digital4Sustainability – Accelerating the Digital & Green Transition in the ICT Industry.

- Programme: ERASMUS-EDU-2023-PI-ALL-INNO-BLUEPRINT — Alliances for Sectoral Cooperation on Skills.

- 4-years transnational initiative funded by the European Commission and counting on 24 partners and 5 associated partners with 13 Member States represented.

https://www.linkedin.com/pulse/green-digital-twin-transition-justin-anderson/

Digital4Sustainability – Accelerating the Digital & Green Transition in the ICT Industry.



- The Consortium includes digital sustainability experts, business associations, universities and education and training providers coming from: Belgium, Bulgaria, Croatia, Estonia, France, Germany, Hungary, Ireland, Italy, Rumania, Slovenia, Spain, the Netherlands.

Digital4Sustainability – Accelerating the Digital & Green Transition in the ICT Industry.

- Digital4Sustainability is a project funded under the Erasmus+ programme, dedicated to accelerating the digital and green transitions within the ICT sector and across European industries. Our mission is to develop and implement innovative training programmes that provide professionals and businesses with the skills and knowledge needed to thrive in a rapidly evolving landscape where digital technology and sustainability intersect.

https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/twin-green-digital-transition-how-sustainable-digital-technologies-could-enable-carbon-neutral-eu-2022-06-29_en

Digital4Sustainability – Accelerating the Digital & Green Transition in the ICT Industry.

In order to contribute to the Net Zero strategy, the project will develop a set of digital sustainability skills through learning programmes that will respond to the urgent and emerging needs of European industry, thus supporting environmental, social and governance sustainability.

https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/twin-green-digital-transition-how-sustainable-digital-technologies-could-enable-carbon-neutral-eu-2022-06-29_en

Digital4Sustainability – Accelerating the Digital & Green Transition in the ICT Industry.

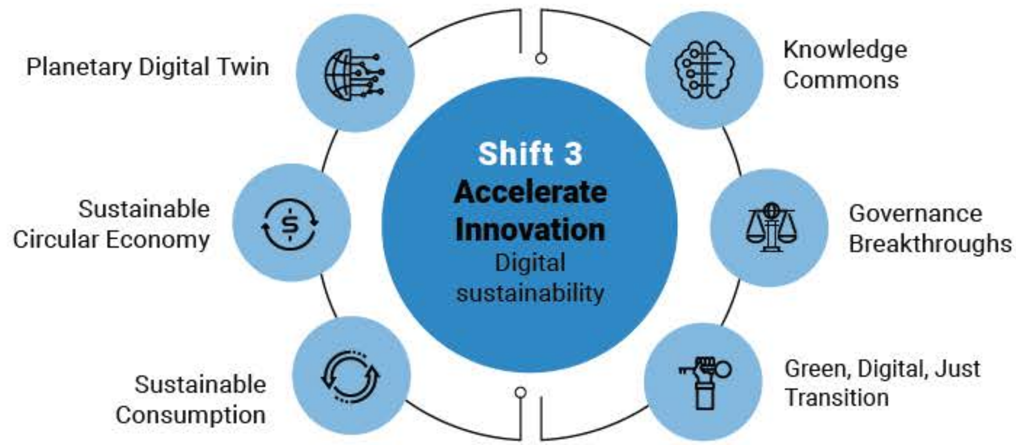
- D4s is developed withing the framework established by the Coalition for Digital Environmental Sustainability (**CODES**)
- CODES believes in the assumption that **digitisation will be crucial** to reach the Sustainable Development Goals.
- An assessment carried out in 2020 demonstrated that the 70% of the 169 objectives of the SdGs can be more easily achieved through the use of digital technologies.

Digital4Sustainability – Accelerating the Digital & Green Transition in the ICT Industry.

- CODES Action Plan: based on 3 shifts and 18 strategic priorities to achieve a sustainable planet in the digital era:
  - Enable Alignment of vision values and objectives
  - Mitigate negative impacts of sustainable digitalisation
  - Accelerate innovation with digitalisation for sustainability

https://zenodo.org/records/6573509

CODES Action Plan



The actual contribution of TIC to GHG ranges between 1,8% y and 3,9%, depending on the calculation method.
High mineral consumption for digitisation.

Committment to increase sustainability by means of digital tools enabling more efficient processes.

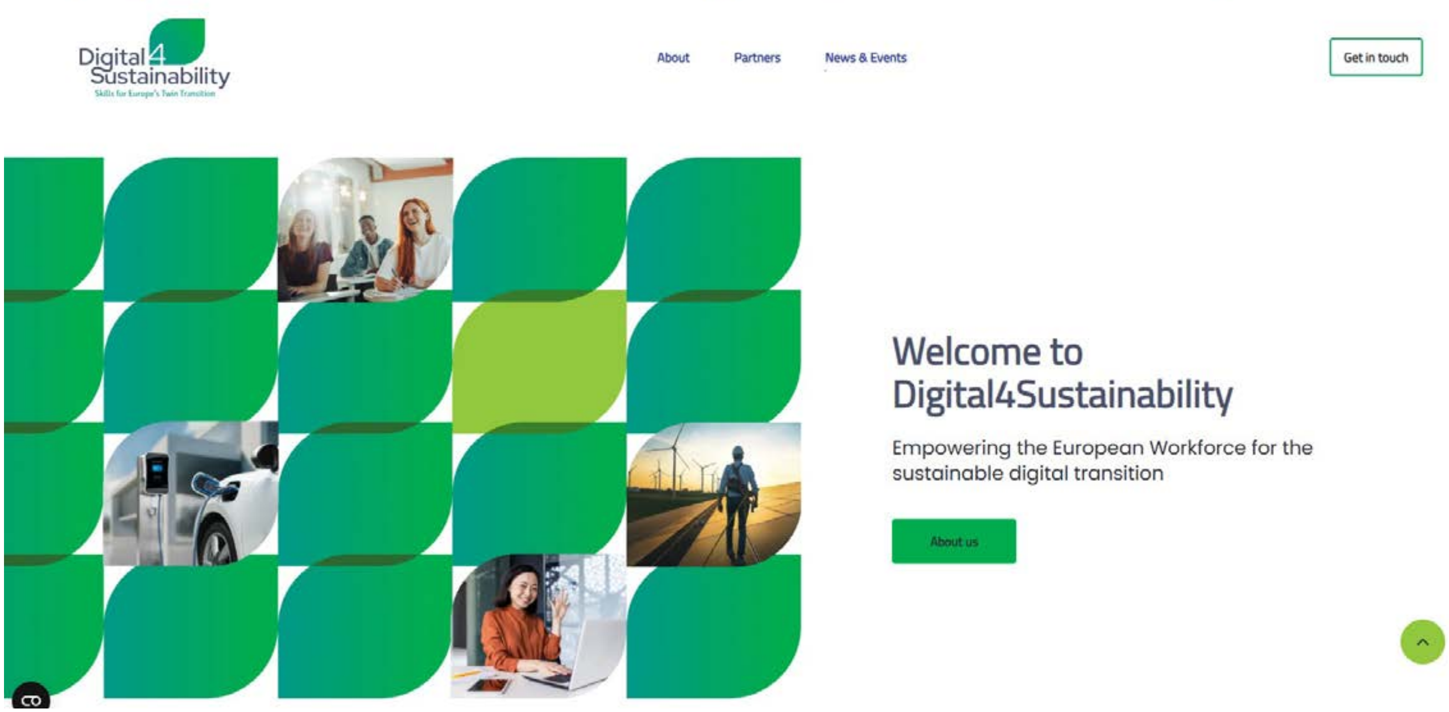
https://www.redestelecom.es/especiales/vamos-hacia-atras-en-los-objetivos-climaticos/?utm_campaign=2-de-octubre-redes_nl_basev4&utm_source=2-de-octubre-redes_nl_basev4&utm_medium=email&sfdcid=*%7CSFDCID%7C*

D4S Target groups

Foreseen activites (WorkPackages-WPs)

- WP1: Project and Alliance Management
- WP2: Needs Analysis and Digital sustainability skills strategy for Europe
- WP 3: Design of Curricula, accreditation criteria, certification framework and development of learning materials.
- WP 4: Pilot of digital sustainabiloty programmes to meet urgent skill needs
- WP 5: Europe wide dissemination and Roll out of project outputs
- WP 6: Long term sustainability strategy and Scale up

https://digital4sustainability.eu/



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Thank you

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Digital Sustainability in Industry

Dr. Roberto Moreno García

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Agenda

1. Sustainability
2. Sustainable development
3. What is Digital Sustainability?
4. What is the relation between SDG and Digital Sustainability?
5. Advantages of Digital Sustainability
6. Digital Sustainability Strategies in Industry
7. Digital Sustainability Tools
8. Real case examples
9. Challenges and opportunities
10. The future

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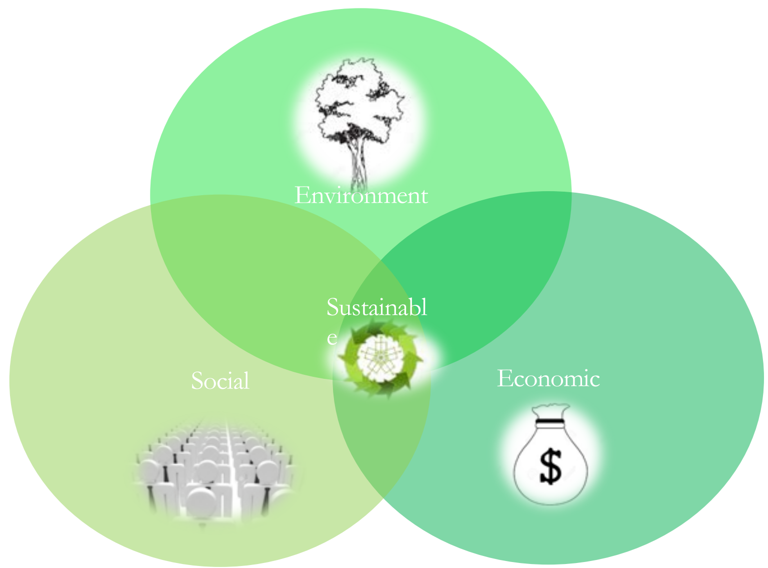
Sustainability

- The viability of a system in all its social, economic and ennvironmental componets, throughout time.



Sustainable development

- Sustainable development is defined as the development able to satisfy today’s needs without affecting the capacity of future generations to satisfy their own needs.

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What is Digital Sustainability?

- Create, use, manage digital resources with the aim to maximise their value for our society, today and in the future.
- Digital sustainability can be defined as the capacity of a digital system to stay active and continuously renovate.

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What is Digital Sustainability?

- Integration of digital technologies in industrial processes
- Optimisation of resources and reduction of waste.
- Circular economy.

What is the relation between SDGs and Digital Sustainability ?

Digitalisation offers innovative solutions to face global challenges such as climate change, inequality and scarcity of resources. By integrating digital technologies in industrial production and in social processes, companies and goverments can :

- **Measure and monitor progress:** Digital technologies allow collection and analysis of huge quantities of data, facilitating the achievement of the SDGs objectives and indicators and impact evaluation of policy initiatives and actions.
- **Resource optimisation :** Digitalisation can improve efficiency in the use of natural resources, energy and material, contributing to the SDGs related to the environment.

What is the relation between SDGs and Digital Sustainability ?

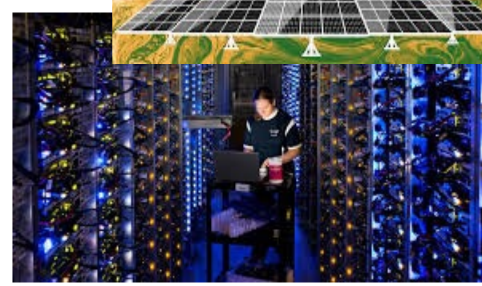
- **Enhance innovation:** Digital technolgies promote innovation and development of sustainable solutions like renewable energy and smart agriculture and cities.
- **Widen access:** Digitalisation can improve access to key services like education,health and energy, especially in marginalised communities, contributing to reduce inequality
- **Promote collaboration:** Digital platforms facilitate collaboration among different actors like governments, companies and civil society to jointly face global challenges**.**

Digital Sustainability advantages

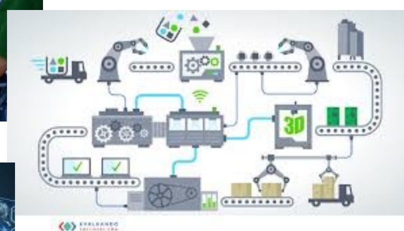
- Reduction of operational costs.
- Improved efficiency and productivity.
- Decreased energy and water consumption.
- Greenhouse gas emissions reduction.
- Increased market competitiveness .

Digital Sustainability Strategies in Industry

- **Ecological product design:** Encourges the creation of durable, repairable and recyclable products.
- **Process optimisation**: implements digital tools to improve efficiency and reduce waste.
- **Use of renewable energy:** encourages the adoption of clean energy in industrial processes.
- **Responsible data management**: Stores and processes data efficiently and securely.



Tools for Digital Sustainability

- ❑ **IoT (Internet of Things):** Real time monitoring of industrial processes, Digital Twins.
- ❑ **Artificial Intelligence:** Supply Chain Optimisation and predictive maintainance.
- ❑ **Big Data:** Analysis of huge volumes of data to take more informed decisions.
- ❑ **Robotics:** Automatisation of dangerous and repetitive tasks.

Sustainability Implementation

- **Manufacturing Industry:** Optimise production processes, reduce energy and materials consumption, improve waste management.
- **Energy sector:** Promote the generation of renewable energy, improve electricity grids' efficiency and develop energy storage solutions.

Sustainability implementation

- **Construction:** use of sustainable material, optimisation of construction processes and reduction of energy consumption in buildings.
- **Transport:** Electric vehicles production, optimisation of transport routes and promotion of sustainable mobility.

Examples

- **Nestlé:** implemented digital tecnologies to optimise its Ha implementado tecnologías digitales para optimizar sus supply chains, reduce food waste and improve the traceability of their products.
- **Siemens:** developed digital solutions for energy efficiency in buildings and industry and for electric mobility.
- **Unilever:** established ambitious sustainability targets and is using digital technologies to reduce its environmental footprint across the value chain.

Challenges and Opportunities

- **Challenges:** Initial investment, resistance to change, lack of digital skills
- **Opportunities:** Improved brand image, access to new markets, compliance with environmental regulations. Sustainability

The future

- Vision of a completely digitalised and sustainable industry.
- Key role of collaboration among companies, governments and academia.

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GRACIAS

DT and MSBE: What Digital Twins Are and What They Are Not

Iván Pena Regueiro

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Contents

What are Digital Twins (DT)?

Digital Twins are entities with their own **unique nature. This technology is increasingly adopted** by organisations to enhance their **product** and **service** portfolios as well as their **operations**.

Ultimately, they lead to **autonomous systems** for specific functionalities.

These types of deployments enable the **evolution** towards **intelligent** systems that learn thanks to the sensorisation of their functional and health state variables.

Thanks to the **sensorisation** of their **functional and health** status variables.

Additionally, they can be deployed or **integrated** into the **real** product, creating a **cyber-physical** system that **combines how it should** behave with **how it actually behaves.**

They virtually represent and simulate real entities so that their behaviour or **response to certain conditions can be predicted**.

*""Industrial sectors require **experts** to lead the implementation of digital twins to help them improve their products, optimise their processes and **enable new customer services.**"*

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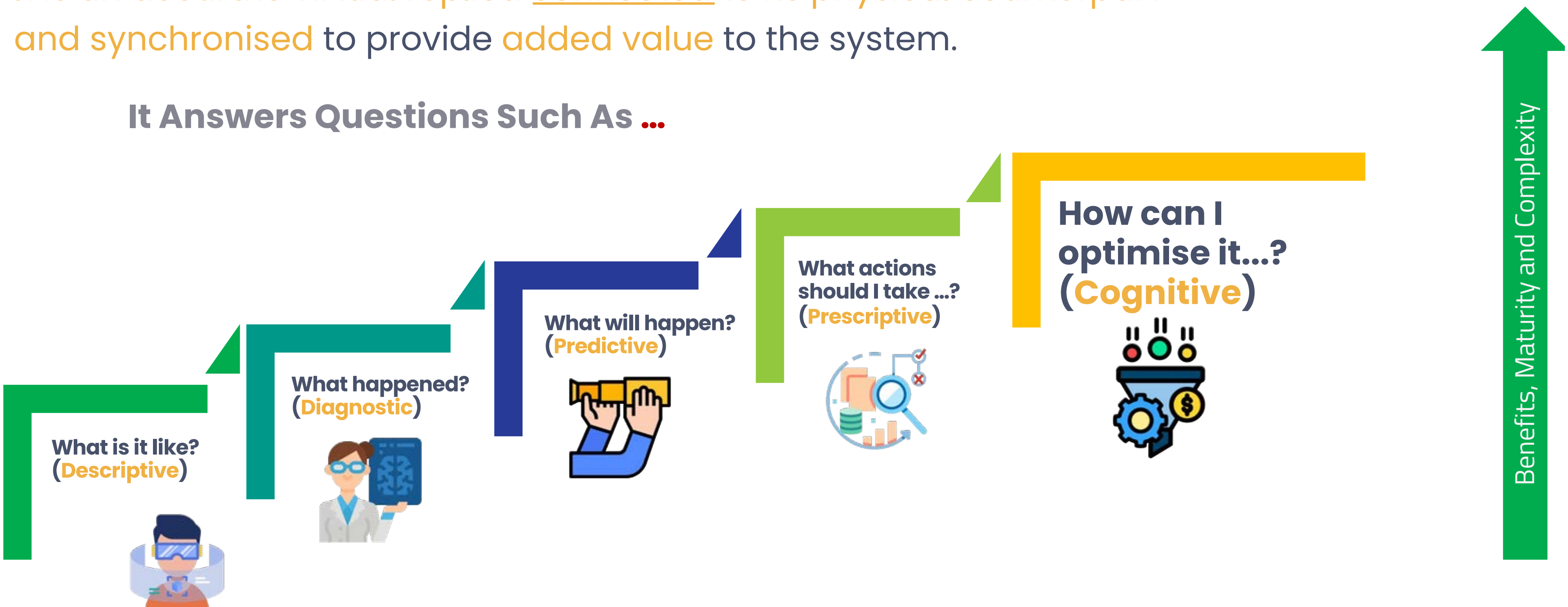
What is a Digital Twin (DT)?

It is an accurate virtual replica connected to its physical counterpart and synchronised to provide added value to the system.

It Answers Questions Such As ...



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Challenges

Identifying the functionalities to start with

And demonstrate the return on investment

Models

Development of increasingly sophisticated multiphysics simulation models

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Hybridisation

Synthesis of models from data and hybridisation with physics-based models

Data and configuration

Management of hardware and software configuration

Backbone

A robust environment for development, execution and sustainment

Human-Machine Interface

Adequate human interaction to simplify user experience

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Advantages of Digital Twins

Anticipating and helping the person

Optimise

Design or system operations

Anticipate

Verification, validation and event responses.

Support

Decision-making

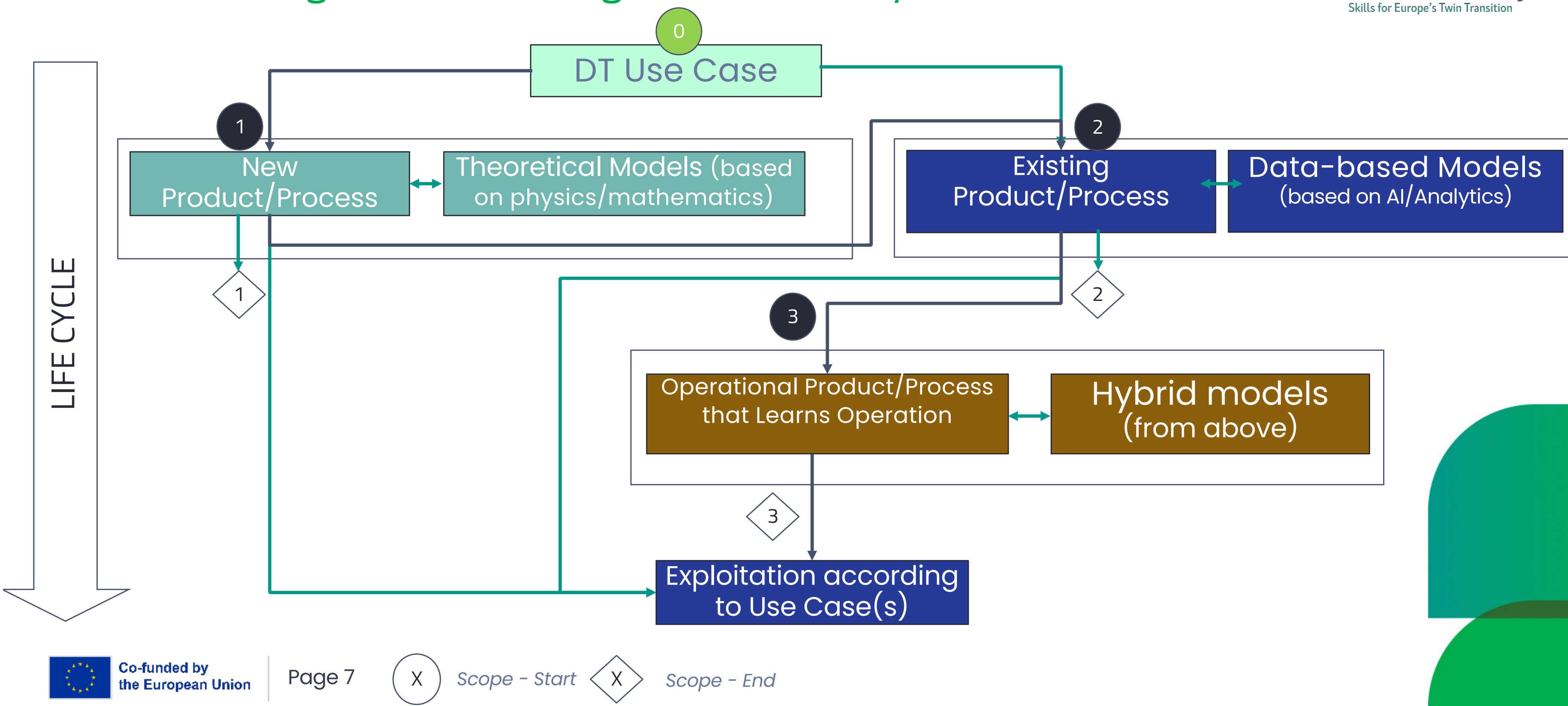
Identify

Deficiencies by comparing the physical system with its digital models

Increase

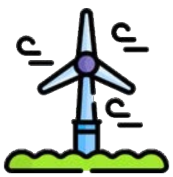
Business lines and functionalities

Model management - throughout the life cycle



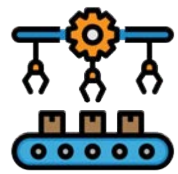
Value of Digital Twins (DT) - Applications

Once the data has been processed, the virtual model can be used to run simulations, study performance issues and generate potential improvements. The goal is to generate valuable insights that can then be applied back to the original physical object.



Power generation equipment

Structures and their systems



Manufacturing operations

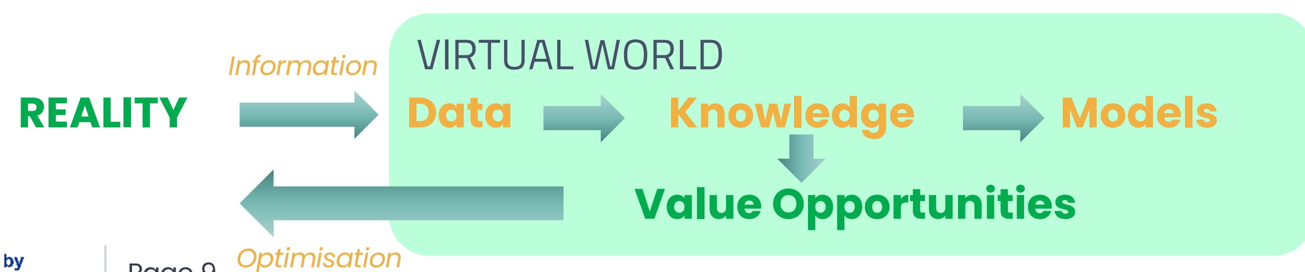
Healthcare services

Realisation of a Digital Twin (DT)

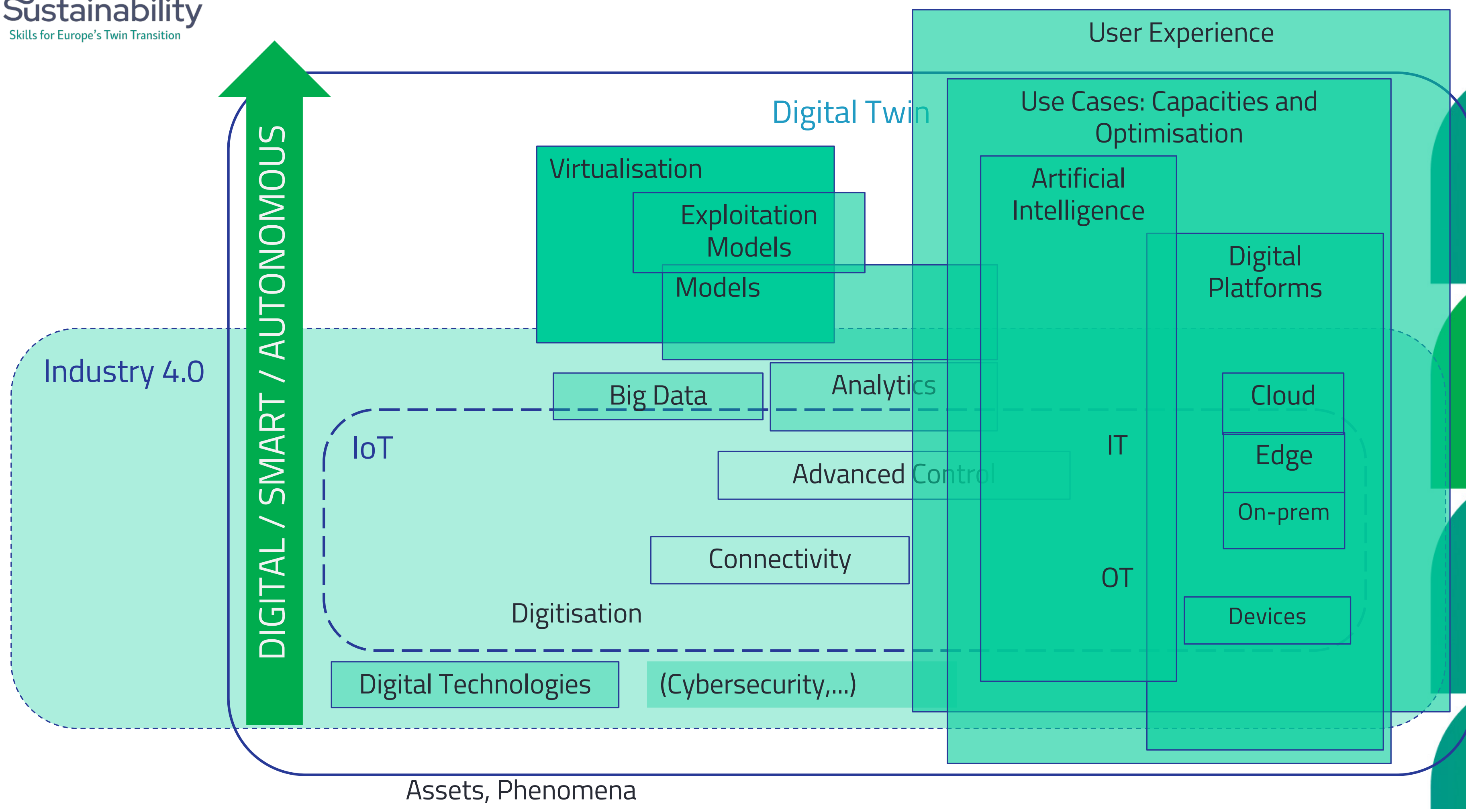
The virtual representation of a real asset is materialised in a set of models and their exploitation applications, typically consisting of a front-end adapted to human interaction and a back-end with the appropriate software for the use case.

This set of elements and software components is executed on a computing, storage and information exchange infrastructure in the form of a digital platform.

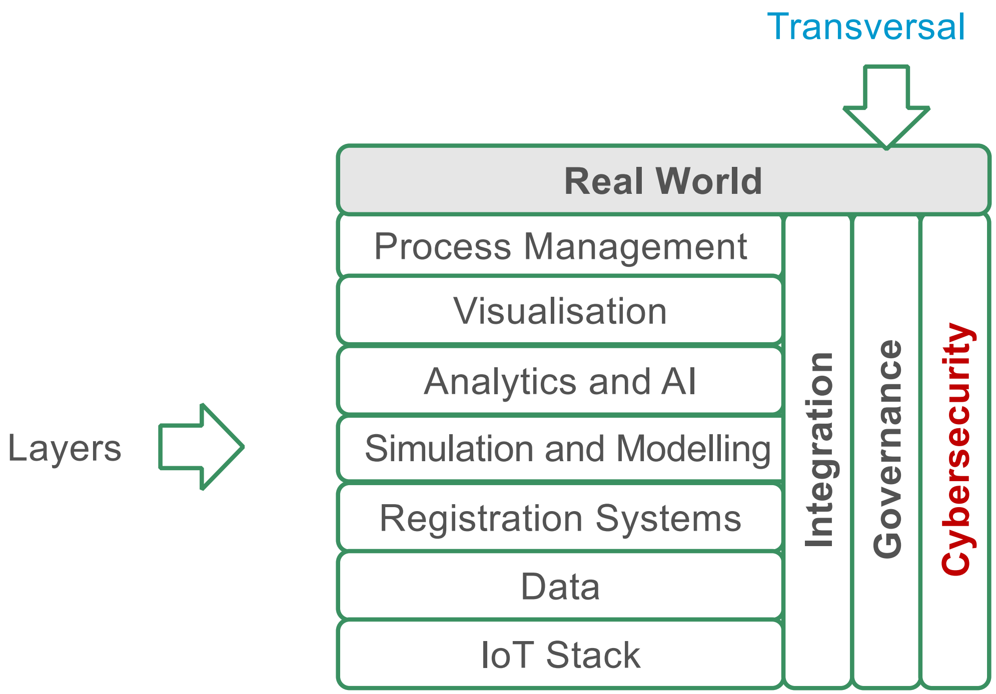
The connection of this replica with the real asset in a bidirectional manner requires the use of sensors and actuators, with the former gathering information from the real world and the latter incorporating the decision-making results of the Digital Twin for the optimisation of the real world.



Digital Twins
IoT/Ind4.0 Differences



Overview of the Architecture



Stanford-Clark et al. 2019 [7]

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RETURN ON INVESTMENT

$$\mathbf{ROI} = \frac{INCOME - INVESTMENT}{INVESTMENT} \times 100$$

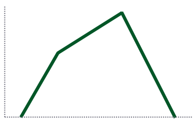
IF THE RETURN ON INVESTMENT IS **LESS** THAN 100%

The investment is not fully recovered in the first year. The percentage indicates how much you earn of the amount you primarily invested, and therefore, how many years it will take to recover it.

IF THE RETURN ON INVESTMENT IS **GREATER** THAN 100%

The full investment is recovered from the first year, and the result obtained reflects the cash surplus generated by the investment.

ORIGINAL CONTRACT - Revenues and expenditures are focused on the initial phases of the project



The contractual relationship ends with the delivery of the product

	Contract	Development	Delivery	Life Cycle
Products				
Digitisation	8,500 K	17,000 K	21,000 K	
Applications				
DT maintenance				
	8,500 K	17,000 K	21,000 K	

INCOME = **€46,500 K**

	Contract	Development	Delivery	Life Cycle
Design and development	4,054 K	8,107 K	4,054 K	
Deployment	2,461 K	4,923 K	2,461 K	
Operation and maintenance	250 K	500 K	250 K	
Digital add-ons	2,210 K	4,420 K	2,210 K	
Licences	50 K	100 K	50 K	
	9,025 K	18,050 K	9,025 K	

EXPENSES = **€36,100 K€**

CALCULATION

$$\textbf{ROI} = \frac{INCOME - INVESTMENT}{INVESTMENT} \times 100$$

TOTAL INCOME	**€46,500 K**
TOTAL EXPENDITURE	**€36,100 K**

ROI = 28.8%

We do not have income from maintenance, nor from app maintenance.

Each year we recover 28.80% of the initial investment, i.e. €13,396,121.
It will take 3.5 years to recover the full investment.

DEVELOPMENT DURING OPERATION - The income and expenses are sustained throughout the life cycle

	Contract	Development	Delivery	Life Cycle
Products				
Digitisation	5,125 K	6,500 K	5,500 K	
Applications				10,000 K
DT maintenance				13,675 K
	5,125 K	6,500 K	5,500 K	23,675 K

INCOME = **€46,500 K**

	Contract	Development	Delivery	Life Cycle
Design and development	1,621 K	6,486 K	3,243 K	4,864 K
Deployment	985 K	3,938 K	1,969 K	2,954 K
Operation and maintenance	100 K	400 K	200 K	300 K
Digital add-ons	884 K	3,536 K	1,768 K	2,652 K
Licences	20 K	80 K	40 K	90 K
	3,610 K	14,440 K	7,220 K	10,860 K

EXPENDITURE = **€36,130 K**

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CALCULATION

$$\textbf{ROI} = \frac{INCOME - INVESTMENT}{INVESTMENT} \times 100$$

TOTAL INCOME	**€40,800 K**
TOTAL EXPENDITURE	**€36,130 K**

ROI = 12.92%

In this case, we will have income from the maintenance of the DT and from applications.

Each year we recover 12.92% of the initial investment, i.e. more than €5,273,623.
It will take a little over 8 years.

CONCLUSIONS

Original contract

- On the other hand, when the contractual relationship ends with the delivery (**ORIGINAL CONTRACT**), the investment takes **fewer years to recover**, since the client pays the full price before the delivery, but the **contractual relationship** ends there. Another important point to highlight is the earlier **obsolescence** of the product, as it is a product with a long-life cycle and would not be updated.

Development during operation

- Maintaining the contractual relationship for more years (**DEVELOPMENT DURING OPERATION**) means the investment takes **longer to return**, but it can **lead to** the **signing of more contracts**, keep workers for a longer time and **create** a sustained **relationship** with the client over time.

Future of Digital Twins [4]

The operational models of companies and institutions are changing disruptively (Digital Transformation), and the digital reinvention in industries with large assets requires an integrated physical and digital view of the assets, teams, facilities, and processes.

Digital twins are a vital part of this realignment.

The **future of digital twins is almost limitless**, due to the fact that increasing amounts of cognitive power are constantly being dedicated to their use. Therefore, digital twins are constantly learning new skills and capabilities, which means they can continue to generate the necessary information to improve products and make processes more efficient.

[4] IBM

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Thank you very much for your attention

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Digital Twins in a water treatment plant

Carlos Rodríguez Alonso

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Agenda

1. Introduction
2. Public tenders
3. Digitisation strategy
4. Digital Twin Platform - Wastewater treatment plant
5. Conclusions
6. Q & A

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Introduction

Digital Twin

A Digital Twin is a virtual replica of a physical system, fed with performance, maintenance, and health information of the real system, keeping it updated throughout the entire life cycle, with the goal of using technologies such as Artificial Intelligence, Simulation and Modelling or Virtual Reality to improve decision-making and generate value.

IoT and Data Connection

Acquisition of the current and past state of the physical Twin

Security and Virtualisation

Security of previously isolated data and deployment of processing systems

Modelling and Simulation

Capabilities to simulate scenarios based on acquired data

AI and Advanced Analytics

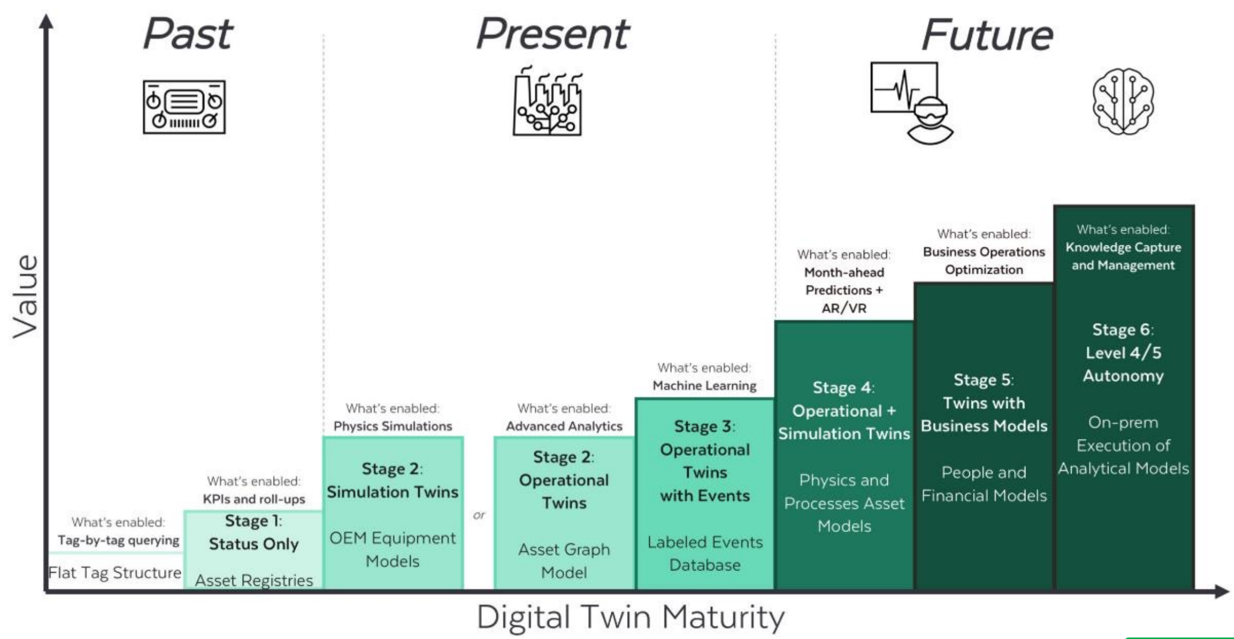
Predictive and prescriptive systems for analysing future scenarios or hidden values

Extended reality

User interface for digital twin visualisation

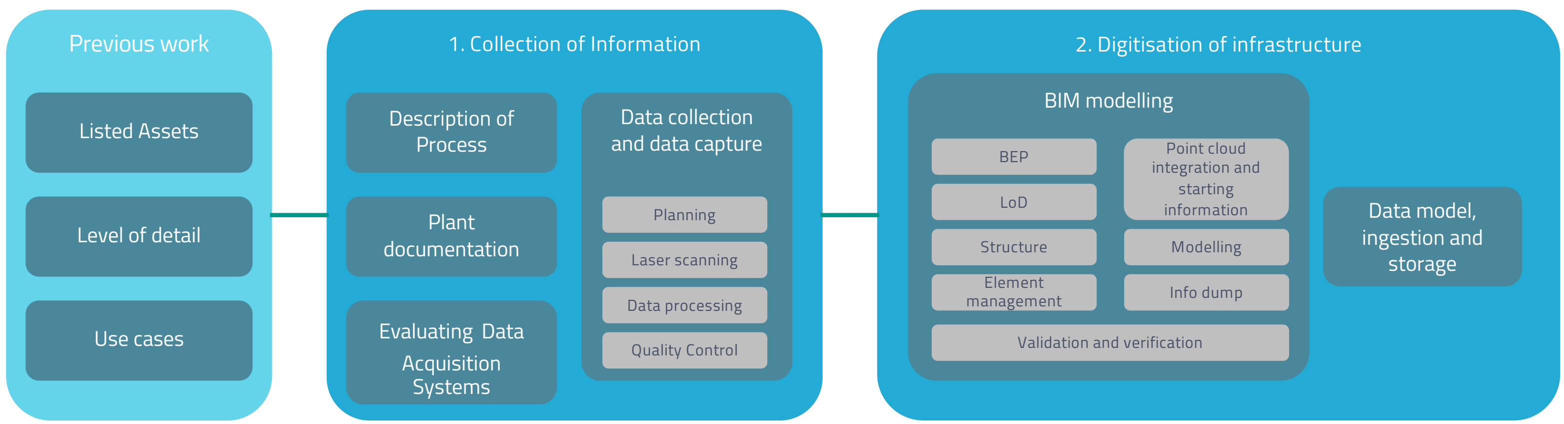
DT Maturity

- Stage 1: State Digital Twin.
- Stage 2: Operational Twin/ Simulation Twin
- Stage 3: Operational Twin with Events
- Stage 4: Operational and Simulation Digital Twin
- Stage 5: Digital Twin with business information
- Stage 6: Autonomous Digital Twin

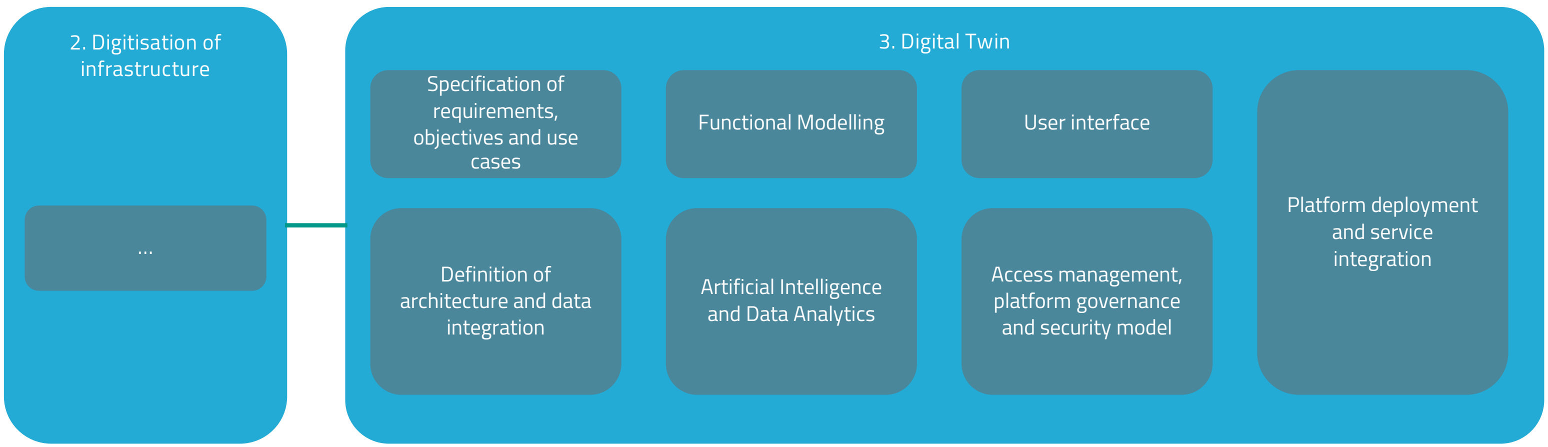


Sameer K. (2017). Digital Twin Maturity Levels [Image]. LinkedIn. https://www.linkedin.com/pulse/evolution-digital-twins-asset-operators-sameer-kalwani/

Digitisation Strategy and Digital Twin



Digitisation Strategy and Digital Twin



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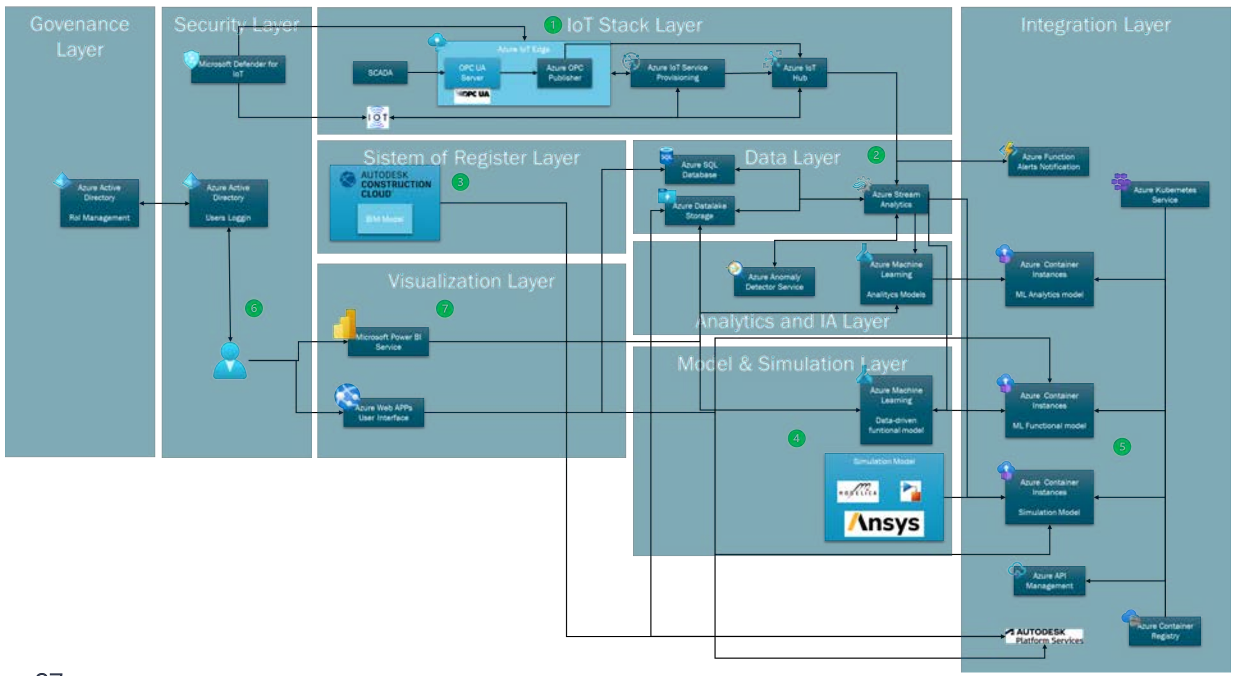
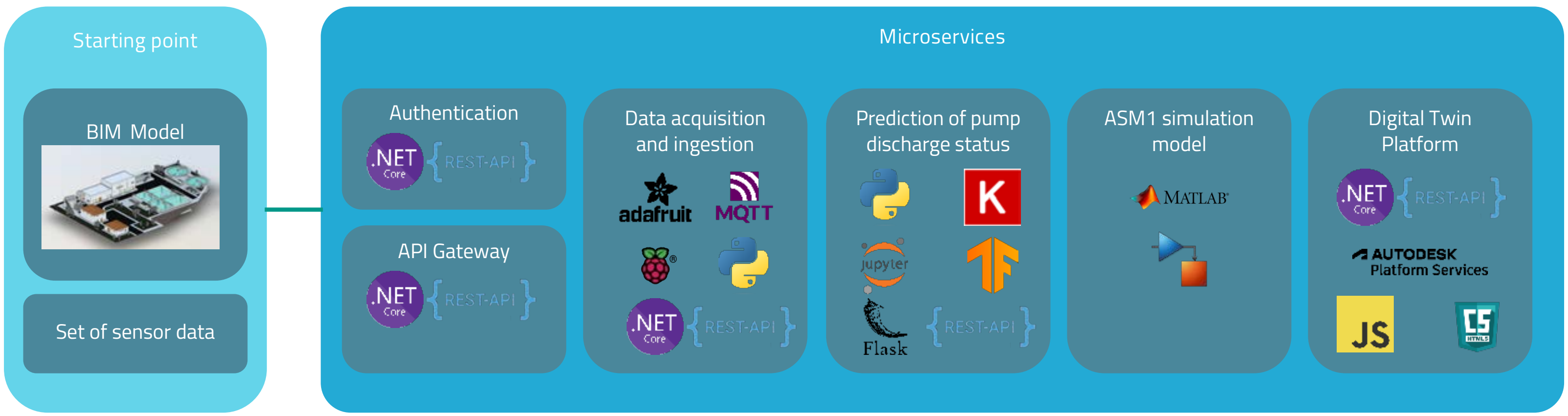
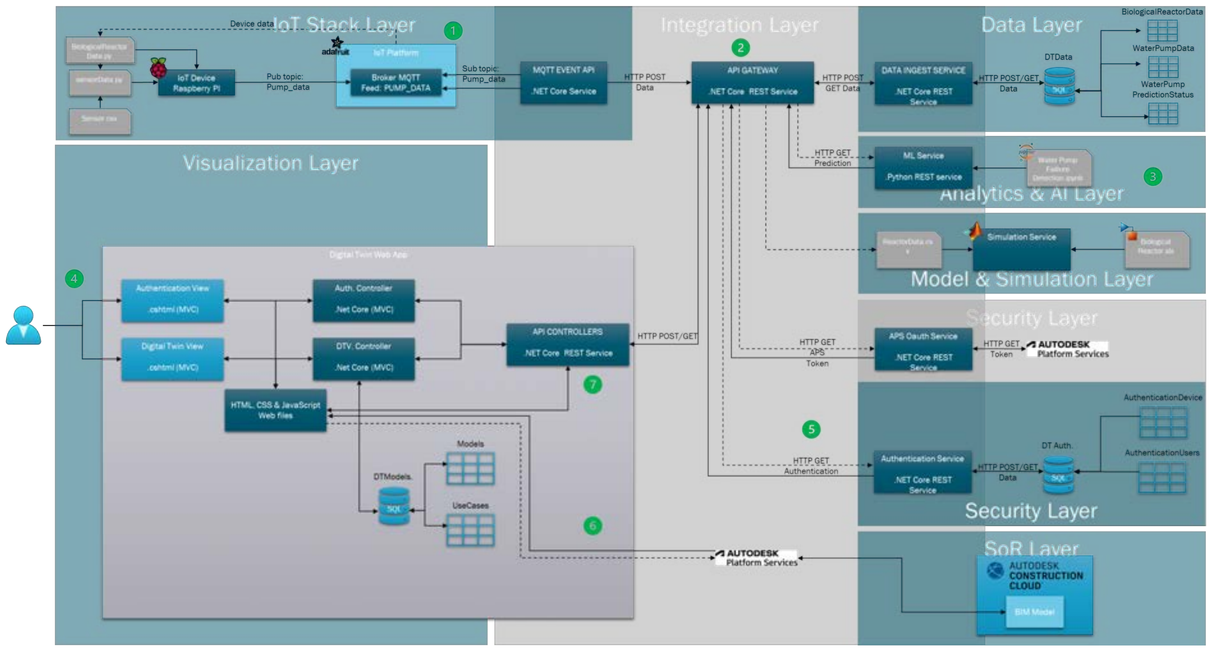
Digitisation Strategy and Digital Twin



Digital Twin Platform - Urban wastewater treatment plants



Digital Twin Platform - Urban wastewater treatment plants: Architecture



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Digital Twin Platform - Urban wastewater treatment plants: Models

ML Model: Statement of assets

Data set
- Operating properties of the pump

Pre-processing
- Cleaning
- Relations
- Network. Dimen.

Results
- Precision: 0.984
- Recall: 0.977
- F1 Score: 0.981

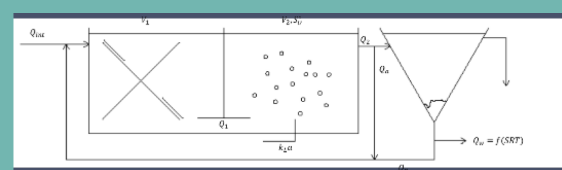
Predictive Model (Flask)
- Objective: Statement of assets at t+10
- Function Cost: Binary Cross-Entropy
- Architecture: LSTM-RNN

Biological Reactor Simulation Model

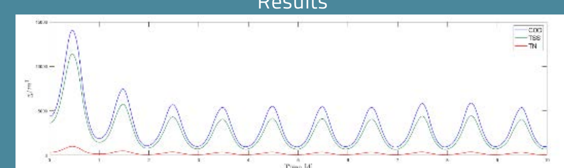
ASM1 → How? → **Starting point**
- Stoichiometrics
- Kinetics
- Initial cycle

→ Peterson matrix → Matlab/Simulink

Reactor:



Results



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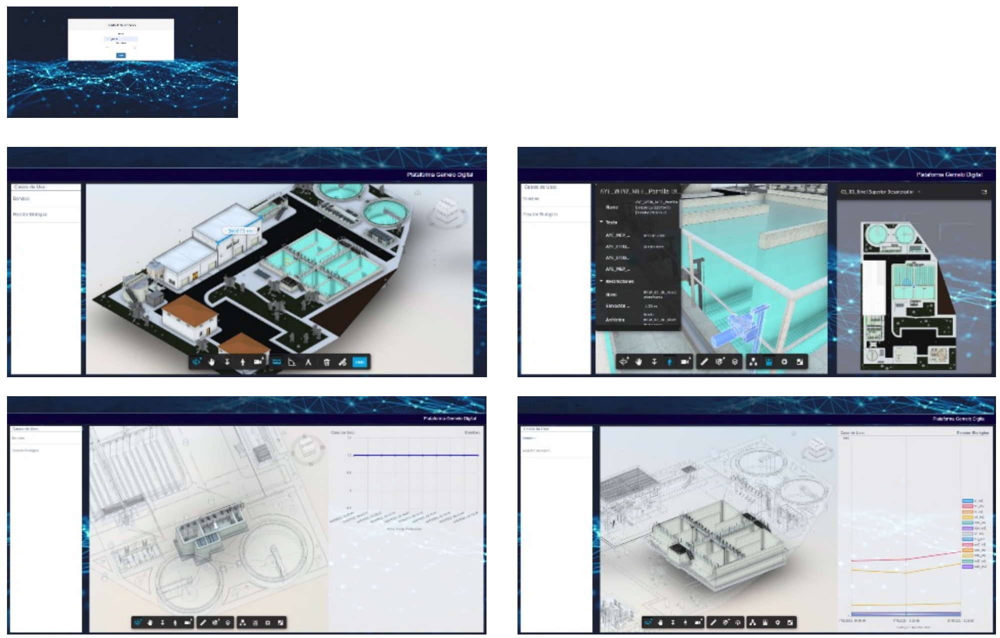
Digital Twin Platform - Urban wastewater treatment plants: Web Platform

- Digital Twin Platform
  - Access and authentication
  - Model data
  - Use cases



Conclusions

Benefits:

- Process optimisation and cost reduction
- Demand predictions
- Predictive maintenance
- Control and prescriptive design
- Detection of anomalous situations

Challenges

- Technological maturity
- Confidence in results
- Organisation-led transformation
- Investment

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Digital Twin for Additive Manufacturing Processes of Mortars

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Agenda

1. Introduction and context
2. Current limitations
3. Digital Twin based solution
4. Process control models
5. Conclusion and call for action

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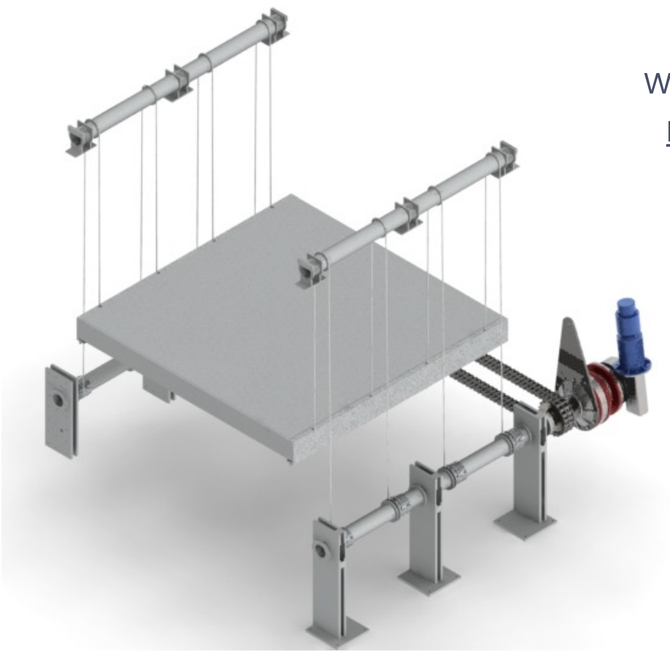
1. Introduction and context



2015

We began working with D-Shape 3D printing technology

ISSUES

- Irregular setting times
- Lack of cohesion in the printed structure
- High porosity
- Low resistance to mechanical stresses
- Limitations in dimensional accuracy
- Need for additional finishing processes

1. Introduction and context

2017 – We adopted Concrete Printing technology

Delta-type Printer
from Wasp Iberia

Model: **WASP 3MT**

This technology offers significant advantages in terms of **design flexibility**, **efficiency** and **cost reduction**.

ISSUES WITH THE DELTA PRINTER

- Difficulty in controlling mortar viscosity
- Limited control over the flow rate
- Rigidity of the delta structure, which is more limited in terms of width
- Printing only on horizontal blueprints
- Frequent maintenance required due to head clogging

2. Current limitations

MAIN LIMITATIONS

- **INACCURACIES IN DOSAGES** → AUTOMATED **DOSING SYSTEMS**
- LIMITED **CONTROL** OVER MORTAR **RHEOLOGY** → CONTROL OF THE **MIXING** AND PUMPING **SYSTEM**
- DEFICIENCIES LAYER-BY-LAYER **DEPOSITION CONTROL** → REPLACEMENT OF DELTA PRINTER WITH **ROBOTIC ARM**

POSSIBILITIES FOR IMPROVEMENT

- AUTOMATED **DOSING SYSTEMS**
- CONTROL OF THE **MIXING** AND PUMPING **SYSTEM**
- REPLACEMENT OF DELTA PRINTER WITH **ROBOTIC ARM**

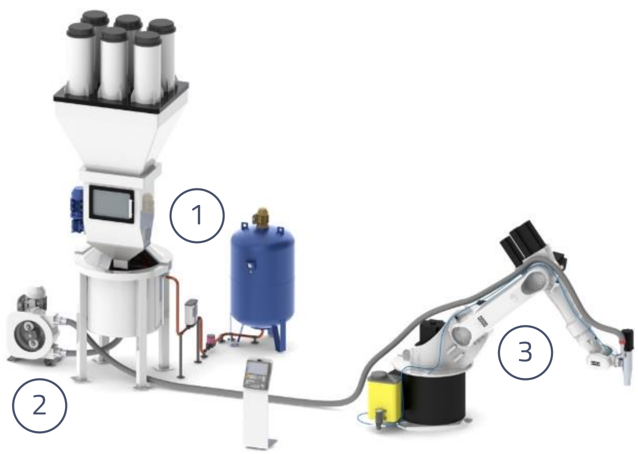
DIGITAL TWIN

- **DATA RECORDING AND MANAGEMENT**
  Traceability and process auditing
- **MIX OPTIMISATION**
  Simulate different dosages
- **REAL-TIME MONITORING**
  Sensor integration and condition measurement
- **FLOW SIMULATION**
  Simulate rheological behaviour
- **REAL-TIME AUTOMATIC ADJUSTMENTS**
  If deviations or errors are detected
- **TRAJECTORY SIMULATION**
  Ensuring optimal material deposition
- **ARTIFICIAL INTELLIGENCE MODELS**
  Continuous learning and fault prediction

1 - Automated dosing systems

2 - Mixing and pumping systems

3 - Robotic arm



3. Digital Twin based solution

MAIN OBJECTIVE

Implement a **new technology based on Digital Twin** that allows us to achieve greater control over the **additive manufacturing** processes of **mortars.**

Speed, precision and quality of the final product

What does a Digital Twin offer us?

1. **Data recording**
2. Real-time **monitoring**
3. **Simulation** of operations
4. Continuous learning

Developing materials and optimising the process

3. Digital Twin based solution

It is essential to ensure **optimum rheological behaviour** of the mortar.

It must **flow** during the extrusion process and, once in place, quickly **regain** its **viscosity and rigidity**

AI MODEL
Predicting the mechanical behaviour of the mortar

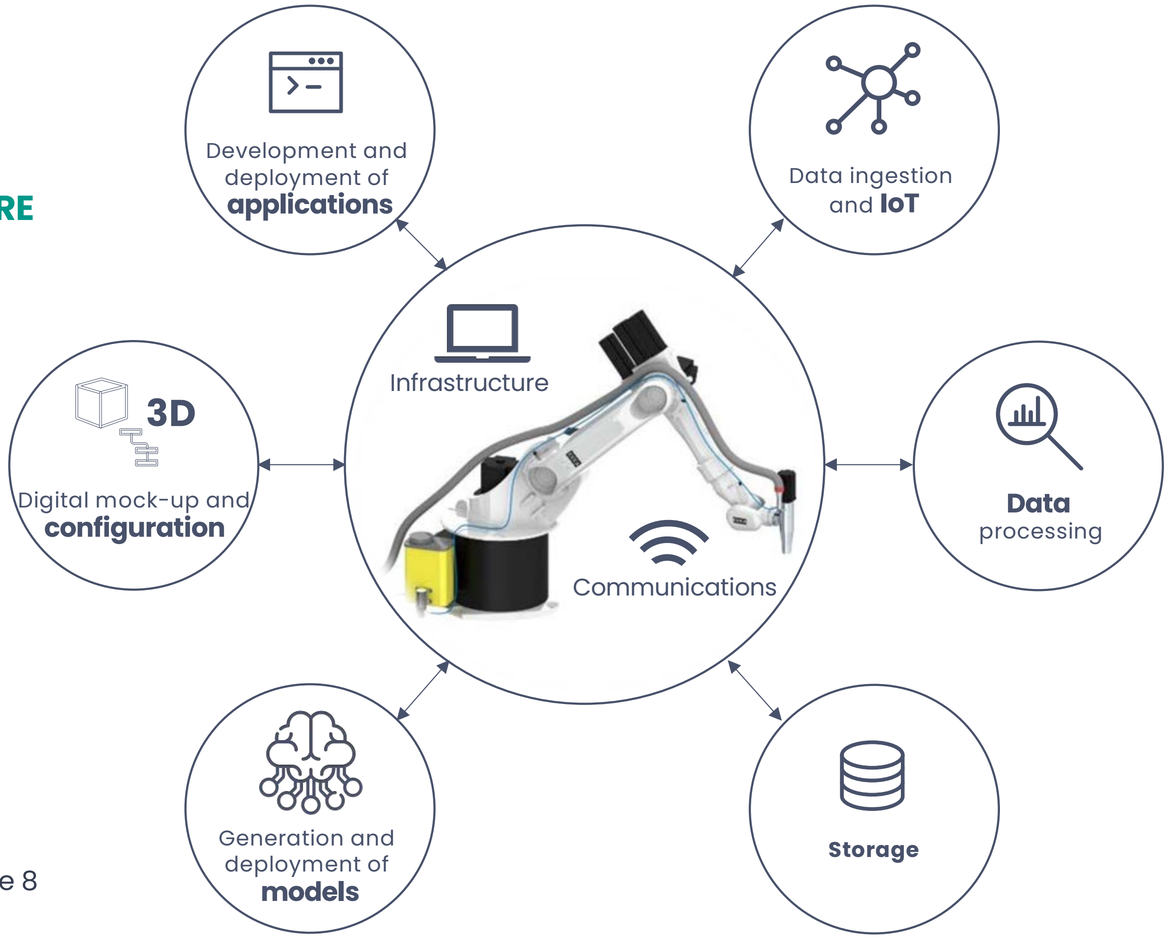
The **quality of the mortars** is essential to ensure and control the **structural integrity and precision** of the printed objects.

RHEOLOGICAL MODEL
Determining the rheological behaviour of the mortar

Rheology and the control of thixotropy, a viscoelastic property that affects the **fluidity and mouldability of the material**, are critical aspects

3. Digital Twin based solution

ARCHITECTURE



3. Digital Twin based solution

BENEFITS OF DIGITAL TWINS

SIMULATION OF MORTAR PROPERTIES
Simulating how different mortar formulas will behave in the printing process. Optimising the development of mortars

PERFORMANCE PREDICTION
Predicting the strength, fluidity and stability of each mix

REDUCTION OF DEVELOPMENT TIME AND COSTS
Simulating different formulas and properties helps minimise physical testing

ADJUSTMENT OF PRINTING PARAMETERS
Speed, pressure and material flow are key to achieving the best print quality

REDUCTION OF ERRORS AND DEFECTS
Predicting deformations or adhesion problems of the mortar in different layers

CONTINUOUS LEARNING
AI models can analyse the data obtained from each print and propose improvements, adapting to each new material or formula.

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4. Process control models

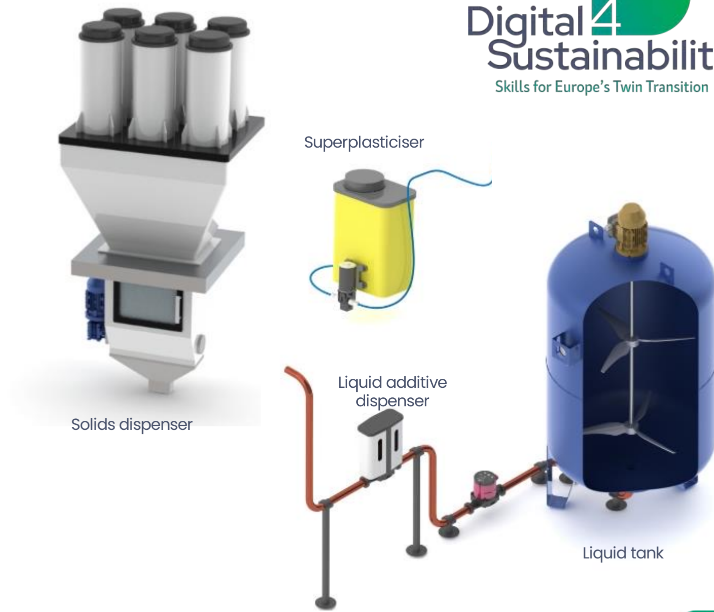
AI MODEL
Predicting the mechanical behaviour of the mortar

Objective: to predict the mechanical behaviour of the mortar based on the historical dosing data.

Purpose: to determine whether the mortar will meet the design requirements of the project, including flexural strength and compressive strength.

Data: the starting data includes the historical dosing records of mortars and the results from compression and flexural tests of those doses.

Models: a comparison is made between 3 regression models to predict the strengths at 28 days.



AI algorithms

- Linear Regression with L2 regularisation (Ridge)
- Random Forest
- Support Vector Regression (SVR)

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4. Process control models

RHEOLOGICAL MODEL
Determining the rheological behaviour of the mortar

Objective: to control the rheological behaviour of the mortar from mixing to deposition.

Purpose: to maintain thixotropic conditions. The mortar behaves fluidly when subjected to agitation and recovers viscosity when the applied force stops.

Data: to adjust the mathematical models, ramp tests are used. A method in which a deformation or stress rate is applied to the mortar that changes linearly over time.

Models: rheological models are used to calculate the shear stress of the mixer and the mixing speed to maintain a specific viscosity.

Rheological Models

- Bingham Model
- Herschel-Bulkley model
- Houska's structural model

5. Challenges and Future Developments

Digital Twins are an ideal tool for **virtually replicating the behaviour** of the 3D printer and its associated processes, **facilitating analysis**, optimisation, and **real-time control** without the need to interrupt physical operations, which significantly accelerates the research and innovation cycle.

ARTIFICIAL VISION

Development of defect detection systems, failure analysis or control of uniformity between layers.

STRUCTURAL STRENGTH SIMULATION

Optimisation of designs, simulation of material behaviour, and long-term performance predictions for the structure.

OPTIMAL TRAJECTORY

Development of dynamic adjustment models to adapt to rheological behaviour (viscosity recovery).

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