



Digital twin

Tested in: Tunnel construction - La Ribera de Folgoso, León, Spain

Tested in: Maritime construction - Gijon port, Spain

Jose Carlos Jimenez Fernandez, TECNALIA



BEEYONDERS

Breakthrough European tEchnologies Yielding cOnstruction
sovereigNty, Diversity & Efficiency of ResourceS

State of the art: In the construction domain, a digital model is still restricted to the stage of a **static designed BIM model** or similar. The more developed application area remains limited to building design and planning work tasks instead of taking advantage of the rich data that is available in construction operations, as the workers performance and safety, environmental aspects, or automated devices.

Ambition: Implement and integrate into a common environment platform the **BEEYONDERS BTs** in construction work process, in which decision are supported by the BTs. Provide the **full situational awareness as expressed in alternative planning** through performed construction site status modeling, workers KPIs and environmental impacts.

Beeyonders developments:

- Modular architecture
- User interfaces (KPIs + Monitoring)
- Input & Output services

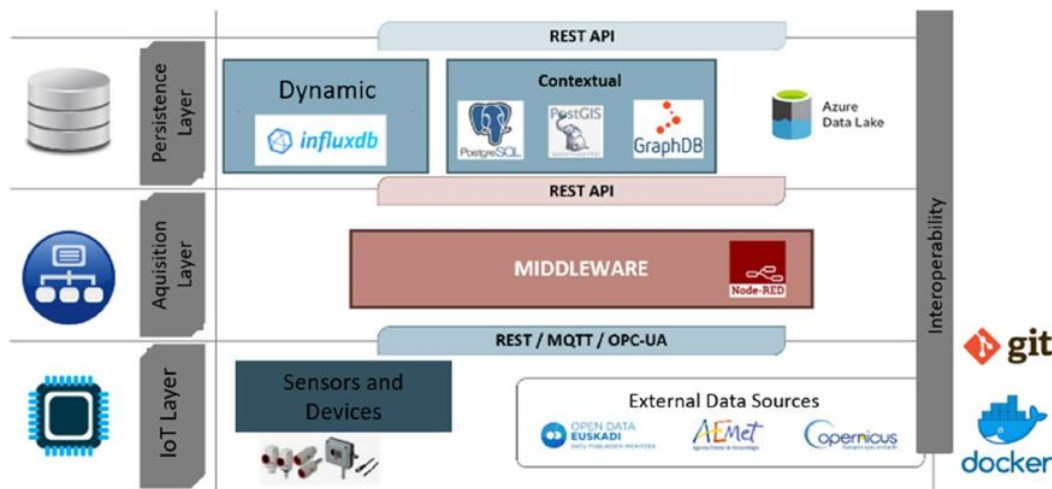


Funded by The European Union



Modular Architecture

The BEEYONDERS modular architecture utilizes a robust hybrid architecture, including **on-premises and cloud-based components**, to realize its vision of a data-driven construction industry. This architecture is designed for scalability, reliability, security, and real-time processing capabilities.





Data acquisition

The Digital Twin has two data-sources related to the Tunnel use-case: the wheel loader and the drone. These provide the following information:

- The AWL sends **telemetry data**, including position and orientation of the machine, position of the arm and of the bucket, battery level. The position of the machine is provided taking the map generated by the drone as coordinate reference. This information is transmitted real-time through the **MQTT protocol**. In the Digital Twin, this communication is managed by the Node-RED middleware. This middleware is responsible of storing the information sent by the AWL into the InfluxDB database.

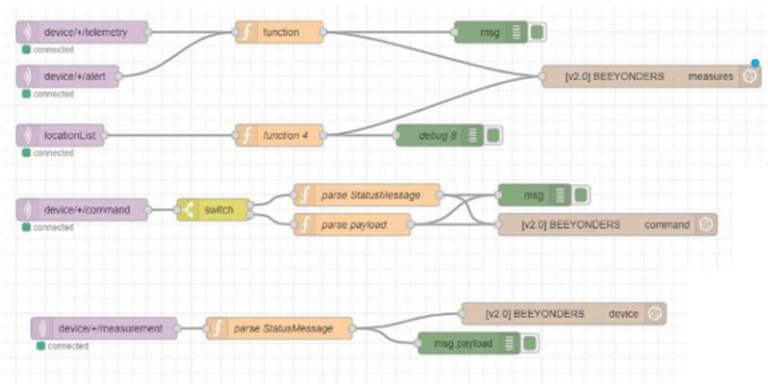
time	arm_positon	battery	bucket_positon	category	id	pose.orientation3D_theta	pose.position_x	pose.position_y	source
2025-06-13T09:01:30.830Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.3261680462716874	17.827796476808735	-3.764635579362	TWC
2025-06-13T09:01:31.910Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.3263552622712794	17.826276711363476	-3.76238617939434	TWC
2025-06-13T09:01:31.850Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	-0.3263848494172545	17.82648879883244	-3.761225186451844	TWC
2025-06-13T09:01:31.130Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.32697681653384	17.82779687918276	-3.76338448667986	TWC
2025-06-13T09:01:31.230Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.326191351841336	17.827215475222828	-3.76303243128802	TWC
2025-06-13T09:01:31.200Z	-15.68888198734863	29	-6.58999986632568	---	beeyonders_AWL_01	0.326115183576834	17.8264837427794897	-3.761521844861142	TWC
2025-06-13T09:01:31.430Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.326119381279959	17.826138788884537	-3.768792758419427	TWC
2025-06-13T09:01:31.530Z	-15.68888198734863	29	-6.58999986632568	---	beeyonders_AWL_01	0.3262713945843895	17.8262123833885	-3.769188364529187	TWC
2025-06-13T09:01:31.610Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.3261622241824566	17.826578915289964	-3.7687974312158577	TWC
2025-06-13T09:01:31.730Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	0.32683811235458	17.82433588888874	-3.758153764911679	TWC
2025-06-13T09:01:31.830Z	-15.699999809265137	29	-6.58999986632568	---	beeyonders_AWL_01	-0.3268212424529464	17.824327881689915	-3.7562855578723145	TWC
2025-06-13T09:01:31.910Z	-15.68888198734863	29	-6.58999986632568	---	beeyonders_AWL_01	0.326833358821884	17.82548827570385	-3.7584891127848255	TWC



Data acquisition

The Digital Twin has two data-sources related to the Tunnel use-case: the wheel loader and the drone. These provide the following information:

- Files generated by the drone (video recorded during the flight, position and point-cloud generated), uploaded to the **Azure DataLake** (REST).





Data acquisition

Regarding the Maritime use-case, it is provided the following information:

Optimized and Bio-Compatible mortars production:

- Sensors: Moisture Sensors (aggregates), Temperature Sensors (concrete/mortar), Wattmeter (concrete mixer), Colonization Sensors (surfaces).
- Communication: MQTT with a gateway for integration with the middleware.
- Material properties, mixing parameters, energy consumption, colonization data (moisture, pH, etc.).

External Data Sources:

- Weather data, geographical data, open datasets.
- Communication: APIs, web services, file transfers.
- Contextual information relevant to the 3D printed caissons (structural & biocompatible)

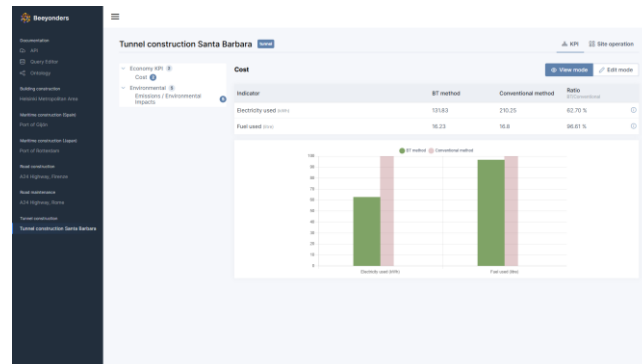
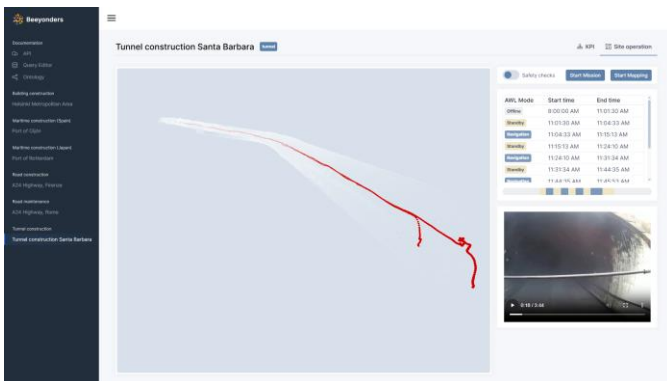


BEEYONDERS

Breakthrough European tEchnologies Yielding cOnstruction
sovereigNty, Diversity & Efficiency of ResourceS

DT Interfaces: KPIs & monitoring visualization – Tunnel use case

The BEEYONDERS dashboarding service is a core component of the project's Digital Twin (DT) ecosystem, designed to provide **real-time monitoring, visualization, and decision-support capabilities** tailored to various construction use cases. It is built on a structured KPI knowledge model using **Semantic Web technologies**, enabling flexible and extensible data representation through a triple store database. This model is complemented by a robust **API layer** that facilitates seamless data exchange between the DT and the dashboard, allowing KPIs and operational metrics to be pushed and retrieved dynamically. The dashboard interface, developed with **AngularJS** and supports advanced 3D visualizations using open-source libraries like ThreeJS and ifcopenshell.

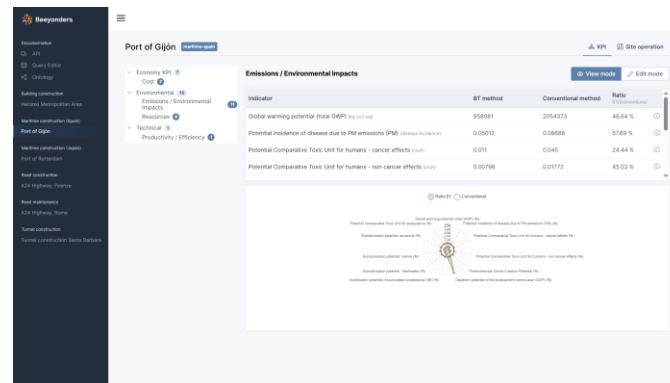
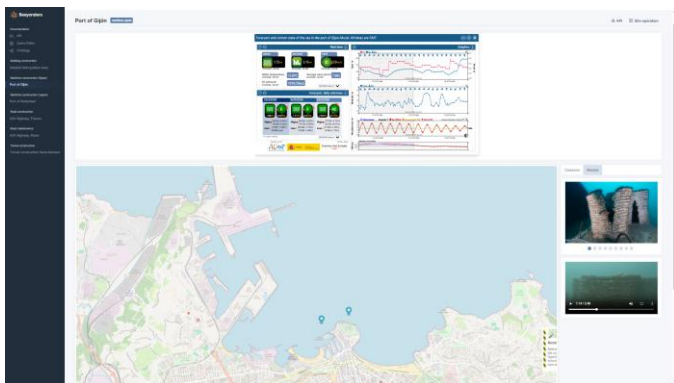


Funded by The European Union



DT Interfaces: KPIs & monitoring visualization – Maritime use case

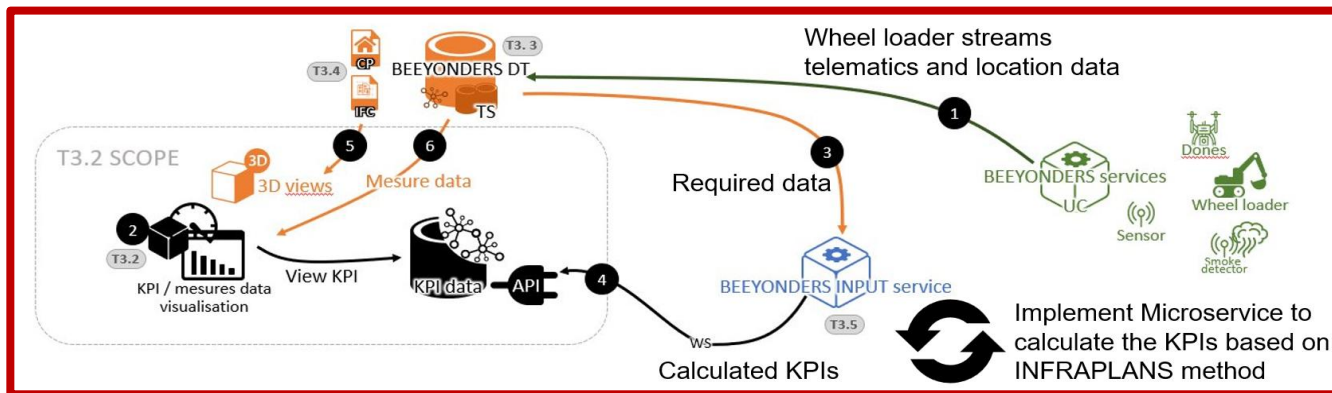
The BEEYONDERS dashboarding service is a core component of the project's Digital Twin (DT) ecosystem, designed to provide **real-time monitoring, visualization, and decision-support capabilities** tailored to various construction use cases. It is built on a structured KPI knowledge model using **Semantic Web technologies**, enabling flexible and extensible data representation through a triple store database. This model is complemented by a robust **API layer** that facilitates seamless data exchange between the DT and the dashboard, allowing KPIs and operational metrics to be pushed and retrieved dynamically. The dashboard interface, developed with **AngularJS** and supports advanced 3D visualizations using open-source libraries like ThreeJS and ifcopenshell.





Digital Twin Services

- Compute selected KPIs defined based on data collected from data sources.
- Address the well-being and safety condition of workers from the prospective of health and ergonomics, planning production control and environmental impacts analysis.
- Generate advanced knowledge for decision-makers.

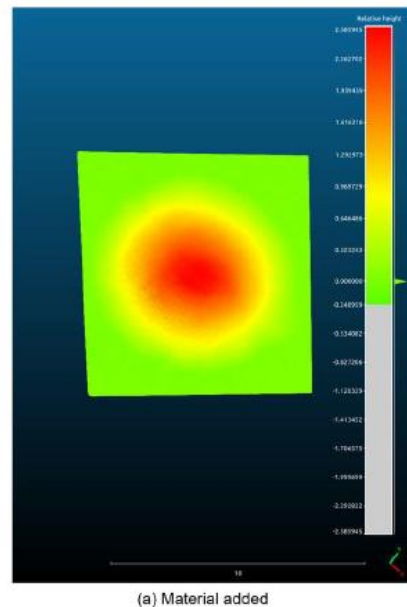
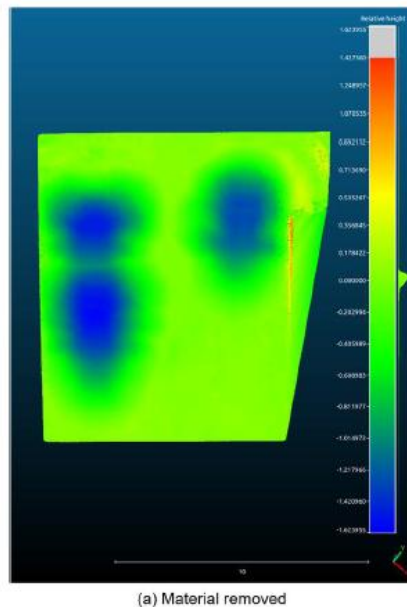
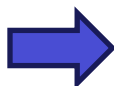
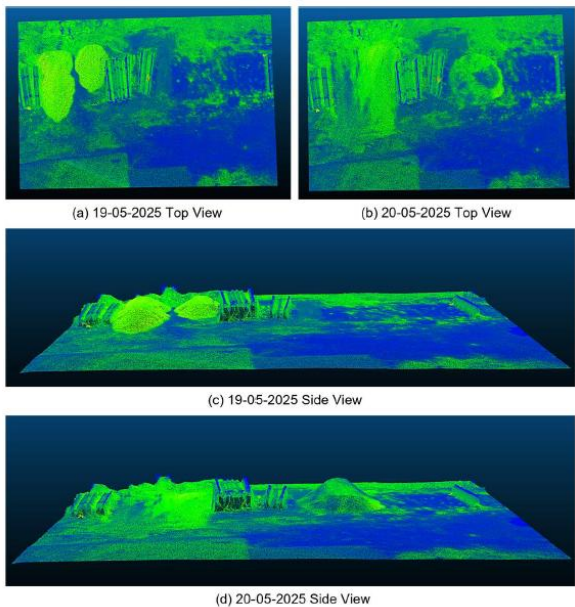




BEEYONDERS

Breakthrough European tEchnologies Yielding cOnstruction
sovereigNty, Diversity & Efficiency of ResourceS

Tunnel use case: Progress monitoring (Lidar data)



Funded by The European Union



Tunnel use case: Environmental emissions

Tier 1 – if only fuel consumption is available

$$E_{\text{pollutant}} = FC \times EF_{\text{pollutant}}$$

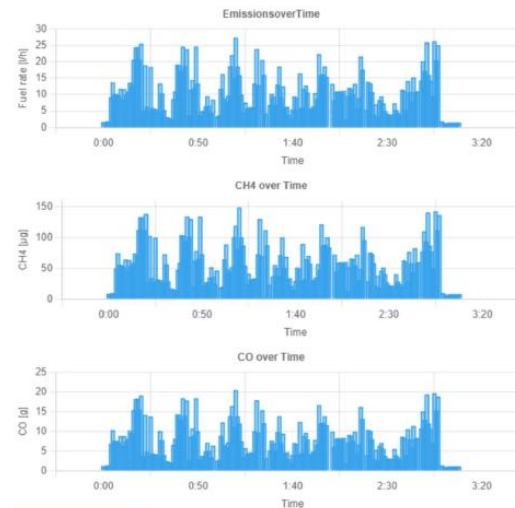
- **E** – total emission
- **FC** – fuel consumption
- **EF** – emission factor for Tier 1 for pollutants: CO₂, CO, NO_x, VOC, PM (diesel fuel)

Tier 2 – if fuel consumption, engine type and category are available

$$E_i = \sum_j \sum_t (FC_{j,t} \times EF_{i,j,t})$$

- **E_i** – mass of emission of pollutant *i*
- **FC_{j,t}** – fuel consumption of fuel type *j* by equipment category *c* and tech type *t*
- **EF_{i,j,t}** – avg. emission factor for pollutant *i*, fuel *j*, category *c*, tech *t*
- **i** – pollutant type
- **j** – fuel type (diesel, 4-stroke gasoline, LPG, 2-stroke gasoline)
- **t** – off-road equipment tech eras: <1981, 1981–1990, 1991–Stage I, II, IIIA, IIIB, IV, V

Today's GWP of the AWL 1,4091 kgCO₂eq.



[Click me to update](#)

