

Pilot sites & testing

Road construction

Location: highway near Gran
Sasso Nord, Italy

Date: 19-25 May 2025

Fabrizio Federici, AISCAT



ROAD CONSTRUCTION

Overall: The Case study demonstrate how the integration of technologies, such autonomous vehicles and drones - together with the Digital Twin and the support of smart wearables to detect interaction between workers and machinery on-site - can optimize the use of resources in road construction tasks.

Technologies and activities involved:

- **Drone** operations for **advanced photogrammetry calculations** and an update of earthworks status on Digital Twin (DT)
- Coordination between **autonomous vehicles (AWL/drones)** and ground personnel (equipped with **smart wearables – RTK**) to implement advanced operational strategies
- **Digital Twin** fed by data streams from drone, ground machinery/AWL, and workers/RTK, supporting route planning, fuel efficiency, and early detection of operational deviations

Partner – Macro activities:

- ACCIONA – WP leader
- AISCAT – Case study responsible
- CATEC - Drone operations
- HIDROMEK – AWL operations
- STAM – Wearable for workers operations and re-routing analysis
- ITAINNOVA – HW/SW for AWL
- TECNALIA – Technical coordinator & Digital Twin Platform
- DTU – Digital Twin
- CSTB – DT Human Machine Interface
- INFRAPLAN – Impact assessment of the technologies
- ICON - Dissemination

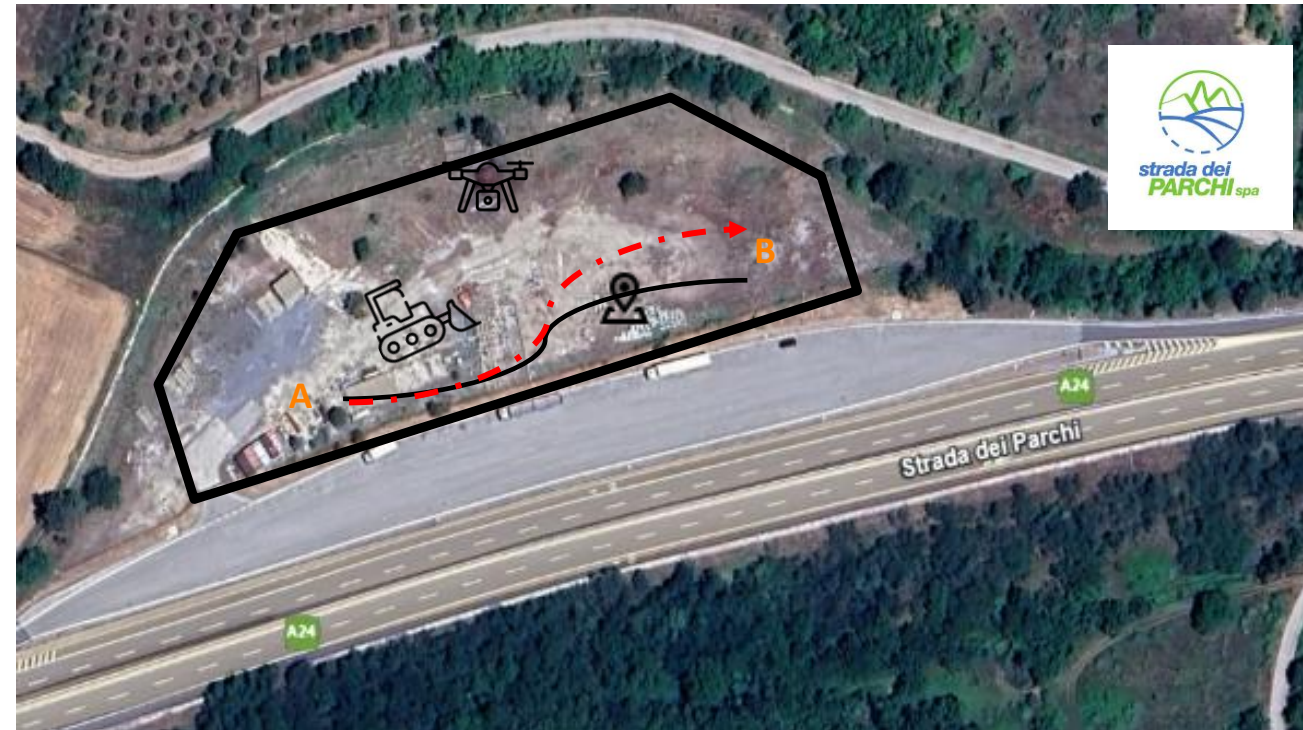
ROAD CONSTRUCTION

Area for the Case Study

- *Strada dei Parchi* highway depot area, located along the A24 motorway
- Near the city of L'Aquila (approximately 1 hour from Rome)
- Surface area of approximately 8,000 m²

Setting the scene:

- Test campaign in May 2025
- 4 active testing days
- Movement of approximately 60 m³ of 14/22 mm gravel
- N. 20 personnel on-site (Beeyonder partners + SdP)
- N. 1 Automatic Wheel Loader 
- N. 1 Drone 
- N. 2 RTK – Smart wearable 



ROAD CONSTRUCTION

- **Use Case Scenario:** simulation of the first set-up on a work zone for road construction, with activities related to the creation of a working area (earthmoving).
- **The approach used to test the case study:**
 - A **basic workflow is agreed upon**, integrating all technologies featured in the case study
 - The **tasks have been broken down** to evaluate potential efficiency gains, including:
 - Tracking worker locations through a heat map based on ground-based routes and activities
 - Proximity safety check (via sound alarm – RTK)) between the worker and the AWL
 - Processing of the minimum/most effective/safest AWL path to reach the work site, in autonomous mode
 - Verification of material loading and unloading activity, in autonomous mode (photogrammetry)
 - To verify the efficiency of the proposed methodology, the **planned activities have been tested and benchmarked against a baseline scenario** using conventional routing and manual guidance of the AWL

ROAD CONSTRUCTION

Basic Flow (1/2)

1. User access to DT interface to check the scheduled program of the “road construction” for that day.
2. DT activates drone to perform an initial photogrammetry (prior to start the construction that day).
3. Drone process captured information, update in DT the initial surface photogrammetry.
4. DT defines the location for AWL task from initial 3D map and in concordance with construction schedule.
5. Workers equipped with smart wearables are positioned at the designated task location.
6. 3D map is updated into AWL to perform the trajectory calculation from initial position (fixed) to task point (variable). Obstacle avoidance check based on the heat map.
7. AWL communicate to DT is ready to perform the activity, and DT send commands to AWL to start operation once everything is ready.
8. AWL reaches task location and performs earthworks (loading/unloading a pile of material).
9. Workers conduct supplementary earthworks in adjacent areas, outside the AWL’s immediate task location, to simulate realistic road construction conditions.
10. Repeat steps n. time until requested material volume is excavated.

ROAD CONSTRUCTION

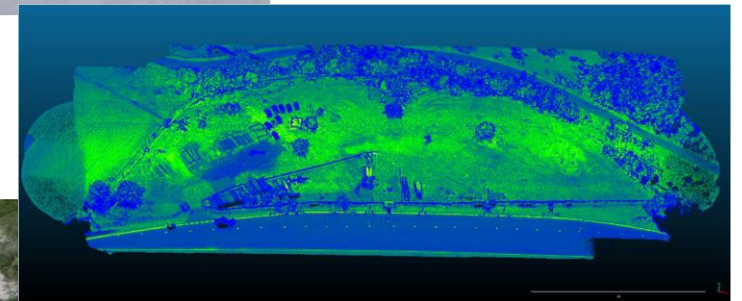
Basic Flow (2/2)

11. During the activities of AWL, IoT data from AWL, SMW/RTK and installed sensors around the road (as environmental) are sent “live” to DT. Machines live data examples are speed, position, orientation, etc.. SMW/RTK data examples are location, proximity alerts to AWL, muscular activity...
12. DT activates the drone to carry out final photogrammetry (conducted at the end of the construction task that day).
13. Photogrammetry from drone is uploaded to DT database.
14. DT database has collected all the live data during activities, and KPIs are obtained off-line to perform:
 - Photogrammetry comparison to obtain productivity with material excavated volume
 - Trajectory record of autonomous machinery and workers are sent to ABM -> route optimisation is performed, and safety of workers is analysed
 - Environmental analyses are performed to obtain related KPIs
 - Workers KPIs are evaluated from data collected during use case
15. Repeat cycle with optimised routes/optimised safety locations for workers

ROAD CONSTRUCTION

Field testing/verifications of the different technologies:

- **Smart wearable/RTK**
 - Record data of workers' trajectories while the AWL is in motion
 - Trigger an alarm when workers approach the AWL
 - Calculate the optimal trajectory for the WL based on the recorded trajectories of the workers → using agent-based simulation.
- **DRONE**
 - Photogrammetry of the area in different time
 - Comparison of photogrammetry to obtain productivity with material excavated volume
- **DT+AWL**
 - Autonomous driving with loading/unloading functions
 - Follow of the best trajectory with worker avoidance



ROAD CONSTRUCTION

- **End User Point of view:**

In Italy, the earth-moving and work-zone construction traditionally involves both managerial and physical separation of ground personnel/laborers' activities from the operations of construction vehicles, such as wheel loaders. The Beeyonders approach has highlighted the potential to integrate these activities while maintaining a high level of safety for ground personnel. This integration allows for increased productivity through the parallelization and rescheduling of construction tasks and through the optimization of tracking of construction vehicle performance, and the expansion of the workforce to include additional professional roles.

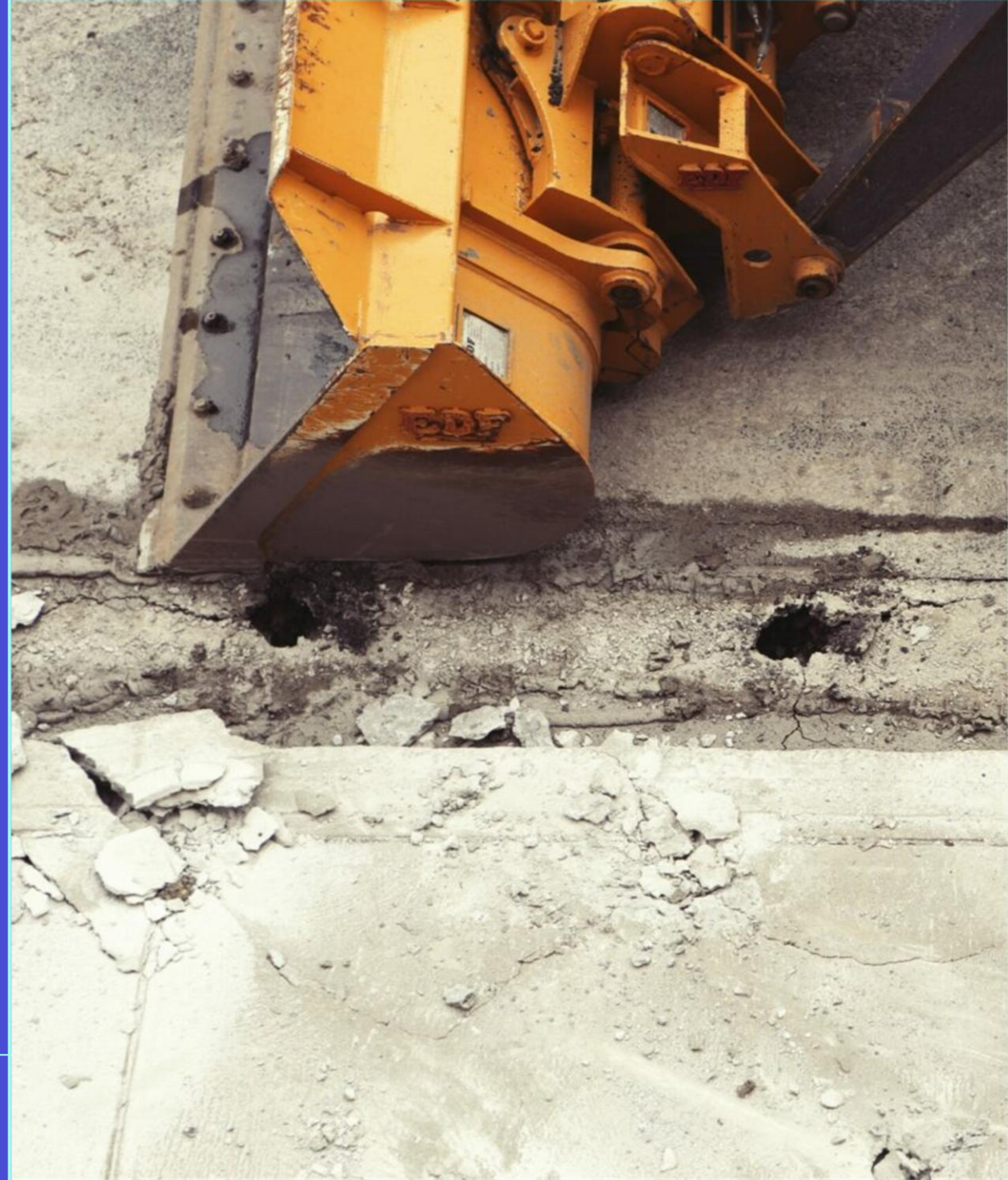
- **Results achieved** - based on a comparison between autonomous and manual driving, and traditional operational activities:
 - **Productivity/social:** Volume of material extracted by the AWL versus operational time → Improved efficiency in conventional tasks, with potential scalability to a broader, previously untapped workforce, including remote workers.
 - **Safety:** H&S from worker measures (SMW/RTK interaction detection with AWL) → Enhancement of existing safety protocols
 - **Environmental:** Fuel and energy consumption, and corresponding CO₂ emission savings → foreseen a reduction of 10% fuel consumption

Road maintenance

Location: highway near Gran
Sasso Nord, Italy

Date: 19-25 May 2025

Fabrizio Federici, AISCAT



ROAD MAINTENANCE

- **Overall:** The Case study demonstrate how the automatization of the maintenance and surveillance activities – thanks to the integration of technologies such ground autonomous vehicles and drones, together with the DT - can optimize the current procedure, enhance safety, and expand the range of workers involved.
- **Technologies and activities involved:**
 - **Drone** for inspection and surveillance tasks: inspection of traffic signs (vertical and horizontal retro reflectivity analysis), detection of dead animals, objects on road, vegetation invading road surface, traffic accidents, etc...
 - **Autonomous Inspection Vehicle (AIV)** for executing all the previous inspection and surveillance tasks in cooperation with the drone
 - **Digital Twin** for managing the equipment used and supporting earlier decision-making by road maintenance stakeholder

Partner – Macro activities:

- ACCIONA – WP leader
- AISCAT – Case study responsible
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ROAD MAINTENANCE

- Area for the Case Study
 - *Strada dei Parchi* highway rest area along the A24 motorway
 - Surface area of approximately 6,000 m² – covering around 500 m of road horizontal sign
- Setting the scene:
 - Test campaign in May 2025
 - N. 3 active testing days
 - N. 20 personnel on-site (Beeyonder partners + SdP)
 - N. 5 (or more) vertical road signs
 - N. 1 Automatic Inspection Vehicle 
 - N. 1 Drone (working > 25m from the highway) 



ROAD MAINTENANCE

- **Use Case Scenario:** simulation of a new inspection procedure in road inspection/maintenance.
- **The approach used to test the case study:**
 - Agreed basic workflow involving all case study's technologies

Tasks are broken down to assess potential efficiency improvements, including:

 - DT platform prioritizing the intervention based on the real needs and extract conclusions giving inputs to improve maintenance protocols
 - Use of ground autonomous inspection vehicles (AIV) for quantitative evaluation of road marking reflectance
 - Use of drones for qualitative evaluation of vertical signage reflectance, vegetation encroachment, and road obstacles
 - To verify the efficiency of the proposed procedure, the planned activities will be compared against existing maintenance practices

ROAD MAINTENANCE

Basic Flow

1. Programme the road section to be inspected, based on the asset database and the road manager's schedule.
2. A drone performs a flyover of the section using LIDAR scanning to detect vegetation, dead animals, and other objects along the roadside. Reflectivity analysis of vertical signage is conducted. Cloud point obtained with reflectivity information is updated into DT database
3. The autonomous inspection vehicle conducts the reflectivity check of road markings and sends the results to the DT database.
4. Based on the data collected during the use case:
 - o Comparison and validation of reflectivity analyses from both devices (drone and vehicle)
 - o Identification of vegetation and obstacles requiring action, based on LIDAR data
 - o KPI assessment related to resource optimization by reducing human involvement in inspections (in terms of productivity, cost, workforce, environmental impact, etc.)
5. Maintenance status is updated using the results from the drone and autonomous vehicle.

ROAD MAINTENANCE

Field testing/verifications of the different technologies:

Autonomous Inspection Vehicle

- Verification of retro-reflectivity of horizontal signage, with varying luminance gradients and geometries.
- Verification of autonomous driving functionalities, ensuring compliance with established routines.

DRONE

- Verification of autonomous recognition of vertical signages and retro-reflectivity check
- Verification of obstacles recognition and reporting, within the prescribed flight limits
- Verification of autonomous functionalities in different scenarios.



ROAD MAINTENANCE

- End User Point of view:

In Italy, maintenance and inspection procedures for signage and obstacle detection on the roadway are segmented into various tasks, carried out by personnel with different qualifications, and managed with a static approach. Beeyonders' approach allows for optimizing these functions: for vertical signage verification, it enables a more resource-efficient approach ("on demand" rather than "at scheduled intervals"), as well as automating and remote-controlling the inspection of horizontal signage. This also leads to increased safety and broadens the potential workforce, including remote workers. The use of drones for obstacle detection in remote areas, such as mountainous zones, finally allows for significant cost savings compared to traditional activities involving personnel and on-road equipment.

- **Results achieved** - based on a comparison between the proposed and current maintenance/inspection procedures:
 - **Safety:** Use of autonomous/remote vehicles for maintenance and inspections → Enhancements in current safety protocols
 - **Productivity/Environmental:** Reduction in fuel consumption by replacing conventional vehicles with drones/AIV for inspection tasks → Projected savings of approximately 50%
 - **Social:** Broadening of maintenance task roles to include a new group of potential workers