

## Monitoring and Validating the Transport of Waste

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The illegal disposal of waste is a growing problem in many countries of the Organization for Economic Cooperation and Development. A weakness with the conventional waste-management cycle concerns the validation and integrity of the transportation process, from collection at industrial premises to delivery at a licenced waste-disposal facility. The on-going Waste Augmentation and Integrated Shipment Tracking (Waist) project, at CLARITY: Centre for Sensor Web Technologies, focuses on this very problem. Waist integrates a triptych of sensing technologies in addressing this problem.

First, the project adopts a standard asset-tracking approach utilizing GPS, enabling remote, real-time tracking of the transporter and (implicitly) the waste payload and producing a simple audit trail. Logs can be subsequently analyzed for suspicious behavior, including deviations from authorized routes or unscheduled stops. However, evidentially admissible data must be more rigorous than that offered by tracking solutions alone.

A second strand to the Waist approach involves deploying sensors on individual waste containers. Sensors include contact sensors on the lids; accelerometers affixed to the containers monitoring movement in the X, Y, Z planes; and pressure sensors. These form an ad hoc wireless sensor network that remains in place for the duration of the shipment journey.

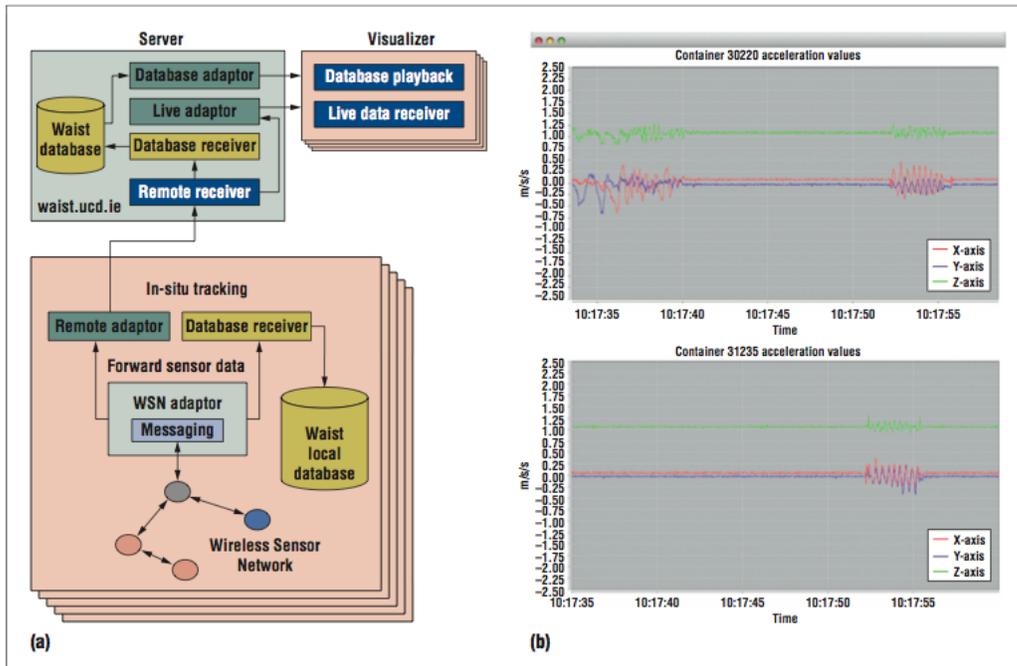


Figure 1. Waste Augmentation and Integrated Shipment Tracking: (a) a schematic architecture of Waist and (b) sensor data from the accelerometers.

Figure 1a illustrates the Waist architecture. An in-situ tracking component captures data from the sensor network and transmits it to a central server for validation, post-processing, storage, and visualization. Heterogeneous sensor integration and interaction is facilitated using Sixth Sensor Middleware.<sup>1,2</sup> Figure 1b demonstrates one possible visualization of the sensor readings. If any individual containers are tampered with or removed from the vehicle, then the associated sensor readings are in stark contrast to other sensors, and such deviations, augmented with the tracking data, can be brought to the attention of the waste disposal authority in real time. At a disposal depot, the

authority can then scrutinize the shipment more closely if needed.

The third component of the Waist sensing triptych involves impregnating the waste itself with a unique and customized chemical marker to provide a spectroscopic fingerprint that can identify the source of the waste. The combination of all three sensing data strands serves as a powerful cocktail that meets the standards of evidentially admissible data.

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## Acknowledgments

this research has been supported by the Irish Environmental Protection Agency (EPA) (*Grant No.*

2008-WrM-Ms-1-s) and science Foundation Ireland (Grant 07/CE/I1147).

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