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The European Commission s Circular Economy Action Plan (CEAP) established the circular economy as a key element to achieve the European Green Deal s 2050 net-zero emissions target. For effective recycling, the waste management sector must adopt efficient waste collection, transportation, and sorting methods. The increasing volume and diversity of materials in waste streams, coupled with demands for low-emission secondary resources, call for new and innovative approaches. Artificial intelligence (AI), particularly machine learning (ML), offers promising solutions for optimizing these processes, such as improving waste sorting with advanced pattern recognition. However, it is essential to assess whether the environmental benefits of ML outweigh its potential impacts, particularly its energy consumption. Recent research highlighted the need to evaluate AI s environmental effects holistically, not just focusing on operational energy use but also considering the other impacts, using Life Cycle Assessment (LCA) methodology. Therefore, our study applied LCA to determine if ML s process efficiencies yield net environmental benefits within waste management. The study assessed four use cases in the plastics recycling chain, covering collection and sorting processes of plastic packaging waste.
The study s objectives were threefold: (i) to compile primary datasets on waste management activities through industry collaboration, addressing data gaps that are often filled with generic data; (ii) to assess the environmental impact of four ML technologies using LCA methodology; and (iii) to evaluate the net environmental benefit (or burden) of implementing ML in waste management.
Four use cases were analyzed: intelligent route optimization for waste collection (Use Case 1), inventory optimization to reduce empty trips (Use Case 2), and two additional ML applications for improving sorting efficiency. The LCAs followed ISO 14040/14044 methodology, with a consistent functional unit of treating one ton of post-consumer plastic waste and considered global warming potential, energy demand, and resource depletion impacts. The study results provide valuable primary datasets and offer novel insights into the environmental trade-offs of AI applications in waste management.

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5.10.P-We468 Bayesian Belief Networks As a Tool to Inform on Plastic Clean-Up Technologies Net Benefits

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To collect and remove legacy plastic, which accumulates in the environment, new technological interventions are being deployed. These so-called plastic clean-up technologies can be installed in inland waterways, such as rivers and estuaries, where they can avoid the further spread of plastic to marine environments. There is however a lack of standardization in reporting plastic removal and unwanted biological bycatch since empirical data is scarce. The goal of this work was to develop, train, and validate Bayesian Belief Networks for plastic clean-up technologies. We propose to use these probabilistic models as a tool to assess the proportion of plastic and biota collection and removal by different clean-up mechanisms. The models can support stakeholders in deploying a clean-up technology by providing the proportion of plastic and biota collected depending on the technology, plastic pollution, and environmental conditions. To train, test, and validate the models, we used a set of experimental data collected in a current flume system run under controlled conditions. To develop the models, we have identified six variables in relation to three key aspects based on their ability to determine plastic removal and the biological bycatch. The type of clean-up mechanisms used (an air bubble curtain, two floating booms with a wheel) is a first key aspect. The intrinsic characteristics of the plastic and biota items (e.g., size, shape) as well as the number of items present have been identified as a second important set of key aspects. Finally, the hydraulic condition (flow velocity) of the waterway in which a mechanism is deployed is also incorporated. Based on the model with the highest technical reliability, simulations will be made to provide relevant scenarios and to evaluate the effect of the variables (e.g., flow velocity) on plastic and biota collection and removal.

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