Journal of Cleaner Production 281 (2021) 125345

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Design, implementation and assessment of a more sustainable model to manage plastic waste at sport events

Augusto Bianchini*, Jessica Rossi

Department of Industrial Engineering, University of Bologna, Via Fontanelle 40, 47121, Forlì, Italy

ARTICLE INFO

Article history:
Received 7 July 2020
Received in revised form
25 November 2020
Accepted 25 November 2020
Available online 1 December 2020

Handling editor. Cecilia Maria Villas Bôas de Almeida

Keywords:
Circular economy
Waste management
Marathon
Assessment tool
Environmental impact

ABSTRACT

The implementation and assessment of sustainable initiatives at sport events has a great importance for researchers and practitioners to improve the effects on the hosting territory. All three pillars of sustainability (environmental, economic and social) must be considered. In running events, such as marathons, one of the main issues is the environmental impact of the great quantity of waste, and particularly of plastic waste. A recent tendency is to shift to a “plastic-free” model. However, some single-use plastic products have unrivalled properties and their replacement with other materials may not be the most sustainable solution, at least in the short term. In this paper, a new model for managing plastic waste at a marathon is proposed. It does not aim to eliminate plastics at sport events, but to better manage waste by increasing collection, and sorting and recycling efficiency, following the circular economy paradigm. To demonstrate the sustainability of the model, a precise and quantitative methodology is applied to an innovative visualisation tool, developed by the University of Bologna, to assess circular initiatives and some key performance indicators (KPIs) to compare the sustainability of the new model to waste management in the previous editions of the same event. With this approach, it is demonstrated that a marathon can be completely sustainable: (i) from an environmental point of view, plastic collection efficiency increased by 120.5%; the recycling rate by 157.0% and the landfill rate decreased by 75.4%; (ii) from an economic point of view, it was demonstrated that, with the technological level of the involved recycling plant, the initiative is cost-effective when the virgin PET price is greater than €776/tonne; and (iii) with regard to the social impact, it was proved that the direct engagement of participants (runners and walkers) and their positive perceptions about the initiative achieved the highest score for the two selected qualitative KPIs (3/3). Moreover, some insights have been derived to improve plastic management, covering different disciplines: technical standardisation of plastics, consumer training and legislative support for technological innovation in the industrial context.

© 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

The introduction and the implementation of sustainability at events, such as sports events, have become an urgent need for researchers and practitioners (e.g. events organisers), to be considered during the planning phase, to manage and improve the consequences of the event activities on the hosting territory. Previous research, conducted above all at large sport events such as Olympic Games and World Cup tournaments, highlighted multiple effects for the host region, with both positive and negative impacts on tourism, travel, infrastructure, education and other sectors. These consequences involve all three pillars of sustainability, which are social, economic and environmental (Coalter and Taylor, 2008; Gibson et al., 2012; Scrucca et al., 2016; Meza Talavera et al., 2019; Li et al., 2019). In order to encourage a positive impact for each of the three pillars, since the 2000s different organisations have provided guidelines for promoting concrete practices to make sports events more sustainable, and tools and methods have been adopted to assess sustainability and specific Key Performance Indicators (KPIs). The International Olympic Committee developed the Olympic Games Legacy, a strategic approach to secure a series of tangible and intangible long-term benefits (e.g. new sports facilities; improved urban infrastructure; behavioural changes; new professional skills) from hosting Olympic Games; and the Olympic Games Impact, a methodology and more than 100 indicators (e.g. network dedicated to public transport; percentage of public transport that

---

* Corresponding author.
E-mail address: augusto.bianchini@unibo.it (A. Bianchini).

https://doi.org/10.1016/j.jclepro.2020.125345
0959-6526/© 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

List of parameters

$C_{collection}$	unit cost to collect plastic waste at the sport event (€/tonne)
$C_{logistic}$	unit cost for the reverse logistics of the collected plastics (€/tonne)
$C_{recycling}$	unit cost to recycle plastics (€/tonne)
ER	energy recovery (MJ)
$\overline{I_{wi}}$	average increase in weight due to residues referred to as a generic polymer i (%)
$\overline{I_{wS_j}}$	average increase in weight due to residues referred to as the generic sampled rubbish bags S_j (%)
LR	landfill rate (%)
RR	recycling rate of the initiative (%)
S_j	generic sampled rubbish bags
$W_{available\ plastics}$	total plastics quantity available for distribution to participants (kg)
$W_{clean\,i}$	total clean quantity of polymer i collected at the sport event (kg)
$W_{clean\,S_j}$	weight of the clean products contained in the generic sample rubbish bag S_j (kg)
$W_{collected\ plastics}$	total quantity of clean plastics collected in the sport event (kg)
$W_{dirty\,S_j}$	weight of the dirty products contained in the generic sample rubbish bag S_j (kg)
$W_{distributed\ plastics}$	total plastics quantity effectively distributed to participants (kg)
$W_{GROSS\ collected\ plastics}$	total gross plastics quantity collected at the sport event (kg)
$W_{GROSS\ collected\ plastics_i}$	total gross quantity of polymer i collected at the sport event (kg)
$W_{NET\ collected\ plastics}$	total net (without rubbish bags) plastics quantity collected at the sport event (kg)
$W_{NET\ collected\ plastics_i}$	total net quantity of polymer i collected at the sport event (kg)
$W_{landfilled\ waste}$	total quantity of landfilled plastics at the sport event (kg)
$W_{plastics\ sent\ to\ recycling_i}$	weight of the polymer i sorted to be sent to recycling (kg)
$W_{recycled\ plastics}$	total recycled plastics quantity at the sport event (kg)
$W_{recycled\ plastics_i}$	weight of the recycled polymer i (%)
$W_{recycling\ ER_i}$	weight of the polymer i sent to energy recovery at recycling stage (kg)
$W_{recycling\ L_i}$	weight of the polymer i sent to landfill at recycling stage (kg)
$W_{recycling\ waste_i}$	weight of the unrecycled polymer i at recycling stage (kg)
$W_{sorting\ ER_i}$	weight of the polymer i sent to energy recovery at waste management stage (kg)
$W_{sorting\ L_i}$	weight of the polymer i sent to landfill at waste management stage (kg)
$W_{sorting\ waste_i}$	weight of the unrecycled polymer i at waste management stage (kg)
$W_{unused\ plastics}$	unused plastic quantity (kg)
k_i	lower heating value of the waste streams sent to energy recovery (MJ/kg)
$p_{virgin\ plastic_i}$	unit price of the virgin polymer i (€/tonne)
$w_{rubbish\ bags}$	unit weight of a rubbish bag (kg/rubbish bag)
$w_{clean\ peroduct\ type\ k}$	unit weight of the clean product type k (kg/piece)
$\#_{rubbish\ bags}$	number of rubbish bags used to collect plastic waste
$\#\ _{product\ type\ k}$	number of product type k contained in generic sampled rubbish bags
$\%_{ash\ residues}$	rate of ash residues from incineration process (%)
$\%_{error_i}$	average percentage of error in recognising good polymer i at recycling plant (%)
$\%_{fine\ plastics_i}$	average percentage of fine plastics in polymer i at recycling plant (%)
$\%_{other\ plastics_i}$	average percentage of other plastics present in polymer i at recycling plant (%)
η_C	collection efficiency of the initiative (%)
$\eta_{recycling_i}$	recycling efficiency of polymer i (%)
$\eta_{sorting_i}$	sorting efficiency of polymer i (%)

uses renewable energy; rate of children who attend school; rate of violent crimes) to measure and understand the impacts in a host city and identify potential legacies. In 2017, the European Commission, in their White Paper on Sport discussed the social and the economic value of sport and its organisation, and provide many positive actions in the areas of cooperation against doping, racism, money laundering and player trafficking, and it is supported by an impact assessment. Several standards for responsible sport, sorted by planning and communication, procurement, resource management, access and equity and community legacy, were defined by the Council for Responsible Sport in 2007, with the aim of providing a complete structure for addressing social and environmental responsibility at sports events. During the International Summit on Tourism, Sport and Mega-events in 2010, the United Nations World Tourism Organisation introduced the concept of sustainability to the discussion about sports tourism and developed a guide for organisers containing concepts, principles and techniques for planning and developing tourism and managing environmental and socio-economic impacts at the local level.

Social and economic impacts have been largely analysed, mostly collecting data from interviews with planners, visitors, residents and other stakeholders. The main results of these studies reveal that, despite some critical issues (such as traffic congestion, increased noise, distortions in the normal functioning of the city and, in some cases, an increase in illegal activities and corruption), positive social and economic impacts of sport events can be recognised and are concerned with the contribution to the development of hosting territories through the generation of some important values, such as national identity, social cohesion and communal pride, and a greater prosperity, for example generated by the attraction of more external investment, the creation of new jobs and the increase in tourist activities (de Subijana et al., 2014; Chen et al., 2018; Camacho et al., 2018; Yao and Schwarz, 2018; Bianchini et al., 2020; Guarnieri et al., 2020).

From an environmental point of view, and according to the previously described guidelines, several mega-events (e.g. the Turin Winter Olympics and the World Cup in 2006; the Summer Olympics in Beijing in 2008, in London in 2012 and in Rio in 2016) were planned with the aim to mitigate negative environmental impacts, as explained by Yeh and Huang (2015) and Collins et al. (2009). Pereira et al. (2017) proposed a Facility Location Problem model, a business tool to determine the best location for the installation of mega-event facilities to reduce the impact of transport. However, as these authors stated, the study and the evaluation of environmental impacts associated with sport events is a rather recent concern and still remains underdeveloped in the existing literature. For large events and mega-events, carbon footprint is typically evaluated in the planning process, but it usually involves the construction of venues and sport facilities (e.g. utilities, structures, bridges, highways) or emissions during travel (Dolf and Teehan, 2015; Manni et al., 2018). For example, Manni et al. (2018) proposed an approach to minimise the emissions determined by an energy enhancement in a renovated Italian stadium. In particular, the typical strategies used for residential and commercial building have been extended to sports facilities to identify a set of technologies to be implemented to reduce energy emissions, comparing different alternatives (photovoltaic system for electricity; geothermal or biomass plant for heating and cooling). Dolf and Teehan (2015) suggested the application of life cycle assessments as a rigorous and transparent approach to evaluate and then mitigate the transport footprint of sports events, such as American football, basketball and football matches, at a Canadian university. Similarly to the previous study, Pereira et al. (2019) assessed the carbon footprint of English Premier League clubs and analysed the travel and procurement practices to reduce this impact. In other previous studies where interviews with key stakeholders were used, environmental impact was investigated with specific questions to understand what resources and activities were involved and how environment quality was promoted, for example (Mallen et al., 2010; Gibson et al., 2012). Nevertheless, quantitative, consistent and repeatable approaches to assess environmental impacts are difficult to provide and few studies exist, while existing tools are often too specific and suitable for few events or they do not provide baseline information for a consistent comparison to other events. To address this issue, Collins et al. (2009) implemented two approaches to quantify the environmental impacts of major sport events, which are the Environmental Input-Output analysis, for an estimation of within-nation impacts, and the Ecological Footprint analysis, which refers more to a global impact, also highlighting some specific weaknesses such as the availability of data and the difficulties in accounting for certain effects, such as information from visitors. Yeh and Huang (2015) introduced the Environmental Economics Method into sport events to provide information about cost/benefit analysis in terms of environmental resources, but the study does not provide case studies or practical implementation. It suggests that it is not ease to incorporate the environmental assessment into the decision-making process to effectively plan solutions to reduce the environmental issues of sport events, such as poor air quality, high energy consumption and transportation, water pollution and significant solid waste generation (Yeh and Huang, 2015). In this paper, the environmental sustainability of a sports event, particularly a marathon, is considered, addressing two challenges in this field: (i) the design and implementation of specific initiatives to improve the environmental sustainability of sports events; (ii) the application of assessment methodologies and tools to measure useful KPIs (not only environmental, but also economic and social) to compare the sustainability of the initiative to the organisation of previous editions of the event or to other activities. In particular, the initiative entitled *#CORRIPULITO* (that, in Italian, means running cleanly for the environment) was designed with concrete practices based on the circular economy (CE) and was applied to a small marathon, held in September 2019 in the Emilia-Romagna region (ERR) in Italy (known as “Maratona Alzheimer”). Running events like marathons do not require specific infrastructure, including a good race-track, but they generate a great amount of waste due to the communication and organisation (before the event) and the distribution of food and beverages at several refreshment points for the athletes (during the race). Some literature exists on waste generation at different events (including sports events). Martinho et al. (2018) analysed how waste is managed at a specific green festival, providing waste generation and composition. Rafiee et al. (2018) investigated the effects of different events on municipal solid waste and its fractions (plastics, glass, metal and cardboard): it concluded that the quantity of total waste significantly increased after all the analysed events and that plastic waste, and particularly mixed plastics, had the highest value. Moving to the grey literature, in 2017,Powerful Thinking accounted for 23,500 tonnes of waste annually generated by the 3.17 million UK music festivals spectators, of which only 32% was recycled while the rest was landfilled. However, due to the lack of knowledge about the qualitative and quantitative characteristics of waste, managing waste and planning improvements in this field is difficult (Manni et al., 2018). No paper for communication and registration, no plastic cases for the food, no plastic cups, cleaning of the course after the race and selective sorting of waste are some initiatives that aim to reduce the environmental impact of running events (Plevnik and Obid, 2015). Another practical initiative (described in grey literature) was implemented in 2018 at the Super Bowl LII stadium: the Rush2-Recycle game aimed to recover more than 90% of waste (more than 40 tonnes) through the recycling of bottles and cans, composting organic materials and collecting discarded items. However, the competition setting and the great variety of used products do not easily allow for the suitable collection and separation of waste, which results in undifferentiated and, in the worst case, dispersed waste in the environment. Atchariyasopon (2017) investigated solid waste that was generated, collected and sorted for the Thai Premier League (football): on average, 0.097 kg of waste per person per football match was generated and more than 85% of the quantity was not properly sorted and was sent to landfill without any recovery of the recyclable part (over 9.10–13.83%).

Plastic, a priority area of the new Circular Economy Action Plan (COM (2020) 98 final), is one of the most impactful materials in the typical (linear) management of waste both in municipal solid waste system and at sport events like a marathon. Plastic can be found in a great number of products at sports events, such as food containers, straws, cups, drinks bottles, but also clothing, gadgets, bags and flags, which become waste mostly on the day of the event, due to their short use. Very few data is available about the plastic waste generated at sport events and only in grey literature: according to UNLEASH, major international sport events create an average of 50 tonnes of plastic waste with a 15–20% recycling rate, determining substantial environmental and economic loss. Planning and implementing an effective waste management system for thousands of participants during a sports event is a complex task. This activity becomes more difficult at a marathon since athletes consume food and beverages during the race, without the possibility of ensuring the correct and differentiated collection of plastic waste that is often thrown on the ground not only in the proximity of the refreshment points but also at a distance of hundreds of metres. This framework is further complicated by the diversity of plastic materials, both mono-materials (e.g. PET, PP and PS) and composite plastic materials, which, when mixed in the same bin, make their sorting and recycling difficult and expensive (Plastics Europe, 2019). This means that the effective collection and sorting of plastic waste during a marathon is an intricate issue. To solve this critical aspect, the recent tendency is to move towards a “plastic-free” model, replacing typically single use plastic products with goods considered more sustainable, at least from an environmental point of view (IOC and UNEP; Croyde Ocean Triathlon). However, the complete replacement of plastic products in the short term, above all at large public events, may not be the most sustainable solution, especially when also considering the other two pillars and mostly the economic side. In fact, single-use plastic products still have unrivalled properties that cannot be replaced by any other materials. These fundamental characteristics are hygiene, practicality, user safety and low cost for the organisation. The adoption of strategies based on the CE concept to manage plastic waste would allow all the positive properties to be retained, and avoiding the negative impact on the environment (Ellen MacArthur Foundation, 2016; European Commission, 2018; Barra et al., 2018; Bianchini et al., 2018; Calleja, 2019).

A circular approach requires the creation of an effective after-use of plastic through the improvement of collection, sorting and recycling rates. Gong et al. (2020) collected and analysed the current initiatives regarding CE and the role of plastics in four fast-moving consumer goods industries in the UK: often a reduction of waste contribution and consumer concern and pressure were identified as among the motivational factors, and they can also be considered elements for new value propositions from a business perspective. According to Barbieri and Santos (2020), circular strategies contribute to the way companies do their business and can be considered sustainable business archetypes. In this context, Dijkstra et al. (2020) investigated the current scientific literature focused on business models for sustainable plastic management, finding a lower number of cases than their implementation in practice and highlighting drivers and barriers: competitive advantages, consumer demand, improving efficiency and reducing raw material costs, regulations and access to funding are some of the main drivers, while high investment and operational costs, system complexity, low consumer awareness and technological issues are the main barriers. The identification of how sustainable plastic management can create value, both for participants and organisers at sports events, is as fundamental as it is for any manufacturing sector. Perić et al. (2019) and Perić and Slavić (2019) conducted a deep investigation into the necessity to define a proper business model for sport events, also recognising environmental sustainability as a key element. However, they stated that the research in this field is still very limited. For sport events and services in general, the identification of the most suitable business model could be more difficult due to the performing of an immaterial experience and the necessity to consider interdisciplinary elements, such as participation motivation, participant involvement, preferences and travel styles, etc.

This paper is focused on the design, implementation and assessment of a circular initiative based on plastic management at a sports event and particularly at a marathon. This complete approach will allow the identification of some cross-sectorial insights to further develop and replicate the proposed model in other sport events, in order to gain sustainable benefits both for organisers and participants. In particular, the paper describes in Section 2: (i) the methodology used to design an innovative management model of plastic waste for a specific Italian marathon, the “Maratona Alzheimer”, according to the CE paradigm; (ii) the equipment and the resources necessary to put the model into practice (before, during and after the event); and (iii) the methodology and the tool employed to assess the impacts (environmental, economic and social) of the initiative. As anticipated, the main novelty of this application is its quantitative approach. Numerous data is collected at each stage of the activity and from different partners. The results, shown in Section 3, are quantitative measurements of the sustainability of the initiative *#CORRIPULITO*, considering the three pillars, evaluated in comparison to the same parameters and KPIs that correspond to previous editions of the same event. The main quantitative results derive from the application of the innovative visualisation tool, developed by the Department of Industrial Engineering at the University of Bologna (Bianchini et al., 2019). According to the characteristics of the tool, it can be adapted to different circular initiatives that involve the single industrial process or the entire business model of a company (Rossi et al., 2020). For this reason, it was applied to the considered sports event. In this paper the focus will be the description of the initiative *#CORRIPULITO* and the demonstration of its sustainability to provide indications and methods to replicate the initiative in the following editions of “Maratona Alzheimer” or other sport events. In fact, through the numerous collected data it will be possible to scale the project for other typologies of sport events, for different materials in different quantities and for other numbers of participants. In Section 4, some specific insights are provided to improve the management of plastic products, where they still have no sustainable alternatives (e.g. at sports events). Finally, Section 5 describes the main conclusions, recapping the potential and the benefits in order to consider and assess sustainability actions from the planning phase of a sports event, extending some considerations to other plastic packaging products.

2. Materials and methods

This section describes the methodology used to implement sustainable initiatives at sports events. The methodology of this research is complete since it combines a theoretical and a practical approach, including the design phase of the initiative and its application. Finally, the effective sustainability of the CE initiative is quantitatively assessed. The specific focus on which the proposed methodology is applied is one of the more urgent issues related to the environmental sustainability of sports events like a marathon, which is the use of a great quantity of single-use plastic products and the consequent generation of a high amount of waste not optimally managed. In this context, the methodology is implemented in the project *#CORRIPULITO* applied to “Maratona Alzheimer” (Italy) with the aim of presenting a new management model for plastic products able to improve the collection, sorting and recycling efficiency through a practical implementation of a CE paradigm.

The framework of the proposed methodology follows the Plan-Do-Check-Action (PDCA) principle, as shown in Fig. 1. Each phase involves some specific sub-actions. The use of this approach to address sustainable objectives, intended as environmental initiatives having also economic and social impacts, is consolidated in the industrial context, as shown in the chemicals industry (Chen et al., 2020), in the manufacturing of grinding balls (Garza-Reyes et al., 2018) and in SMEs for energy optimisation (Prashar, 2017). In a sustainability context, PDCA is also used by Agostinho et al. (2019) as tool to support the framework of a new model to assess sustainability, while Nsafon et al. (2020) uses this approach to provide coherence between the planning phase and the implementation phase of the optimal hybrid technology combination in a rural grid system.

In this paper, considering the specific circular initiative based on the improved management of single use plastic products in a marathon, the phases of the methodology were developed before, during and after the event.

(i) The design of the circular initiative (PLAN – before the event) provides, as outputs, the procedures, equipment and resources necessary for the project.
(ii) The practical implementation of the initiative covers all the temporal stages (before, during and after the event – DO) and allows the collection of real data about the initiative.
(iii) All the data collected in previous phases and from other sources is used to feed the tools selected to measure the sustainability of the event (CHECK – after the event).

All the insights and the considerations derived from previous phases are collected in the Discussion section, after the quantification of the results, and are elaborated to improve and replicate the initiative (ACT).

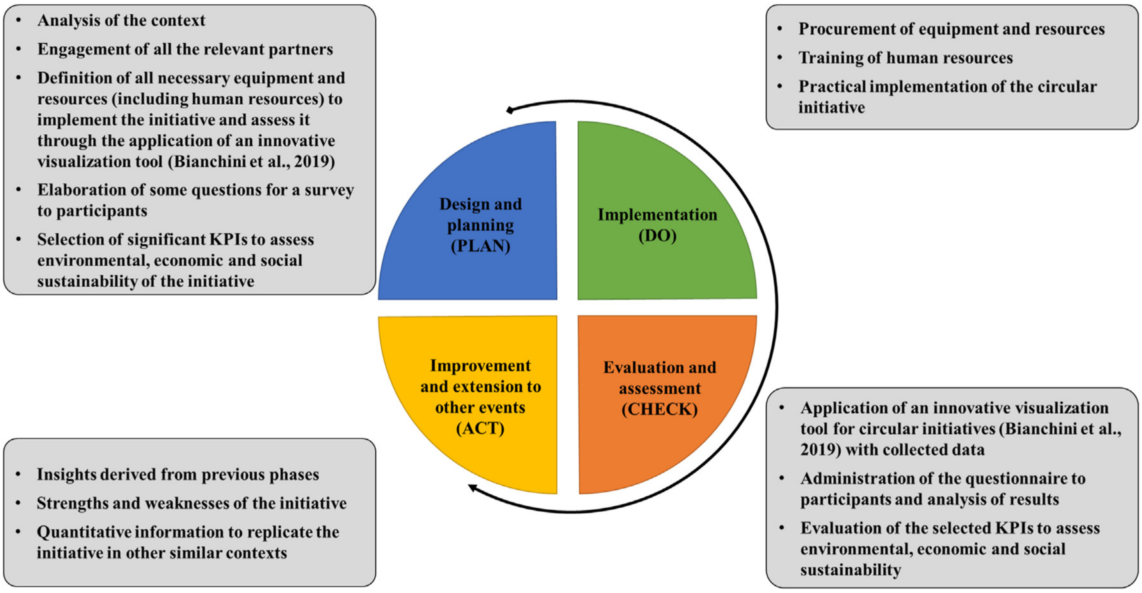


Fig. 1. PDCA approach applied to effectively implement sustainable initiatives based on the circular economy at sports events.

2.1. *Design and planning of circular initiatives for sport events (PLAN)*

For the design of the circular initiative (before the event), the starting point was the analysis of the context. As proposed by Sánchez Levoso et al. (2020), this sub-action aims to identify the key aspects of the context in which the circular initiative is defined, through a review of strategic documents, the identification of key elements and the collection of current and historical data about the event. By adapting this approach to a circular initiative about plastic management at sports events, the proposed methodology consists of the study of the guidelines defined by different organisations and other literature sources active in this field on an international and national/regional level, with the aim of identifying existing experiences with CE and environmental sustainability in the specific situation. Focusing on waste management, the main suggested tactics and actions are summarised in Table 1.

The main guidelines were merged with the characteristics of the selected event (the key elements defined by Sánchez Levoso et al. (2020)), which was analysed in relation to the issue to solve, that is a more sustainable management of plastic waste to reduce its negative impact on the environment. The “Maratona Alzheimer” is a charity sports event dedicated to three main important topics that are: (i) the promotion of sport in the territory; (ii) the dissemination of information about Alzheimer's disease; and (iii) the collection of funding for the prevention of and the research on the disease. Due to the increasing attention on the environmental sustainability of sport events, the marathon's organisation team had already incorporated some actions, such as the appointment of a dedicated person for the waste separate collection, the location of a drop-off point at the finish line, and the replacement of single-use plastic tableware with compostable ones. However, the results were not so satisfactory, in both environmental and economic terms. In fact, proper waste separate collection was not conducted at the finish line and the issue of waste collection remained along the route of the race. Moreover, the procurement of compostable tableware was not sustainable from an economic point of view. Some difficulties could surely be derived from the particularity of the marathon. Despite the fact that “Maratona Alzheimer” can be classified as a small-scale event (according to the definition in Gibson et al., 2012), it presents some complex aspects: (i) the complicated organisation of the event that includes different

Table 1
Recommended tactics and actions for waste management at sports events.

Level	Recommended tactics and action for waste management
International Source: Council for Responsible Sport – A practical guide to hosting radically responsible events (Council for Responsible Sport)	• Make a plan – define a clear framework for waste diversion for the entire event production team (key waste items; objectives by event location; description of operations; instructions; site map with waste management; measurement of waste). • Waste hierarchy – provide priorities for waste management: reduce, reuse, recycle (3Rs); donate; compost and trash.
International Source: David Chernushenko – Greening our Games (Chernushenko, 1994)	• Waste audit – determine what types and quantities of waste are generated during the event and the costs of the existing waste management system. • Action plan – define strategies to obtain waste management goals. Concrete steps include: 3Rs; dispose safety; sell or donate; educate and communicate. • Re-audit and revise action plan – Define specific and more detailed objectives.
National/Regional Source: UISP Emilia-Romagna (Italian Union Sport for Everyone) – Manual for sustainable sport events (UISP Emilia-Romagna)	• Involvement of waste managers – organise a specific service for waste management along the entire route of the race. • Reduce – avoid unnecessary products that become waste in the short-term. • Waste collection – plan the right number and location of waste collection points. • Communication – disseminate the choices/actions for environmental sustainability, above all if they involve the participants.

distances and types of race along the same track and at the same time; (ii) a wide variety of participants in great numbers when compared to the scale of the event and the hosting territory; (iii) the characteristics of the track that is outdoors and in an open loop; and (iv) a short timeslot for the initiative. Following Sánchez Levoso et al.'s (2020) methodological approach to analysing the context, quantitative information about these criticalities were collected and summarised in Table 2.

With the main idea to divert the single use plastic products used in the marathon from the environment and landfill and to foster recycling as the optimal solution for this product category, according to waste hierarchy and CE principles, the proposed initiative must be focused on a proper collection and separation of plastic waste. Due to the great variety of plastics available in products (as explained in Section 1), a proper separation of plastic waste does not mean simply a division from other materials (like paper, organic or mixed waste), but is intended to sort different types of polymers. Providing well-separated flows of plastics, sorted by polymer, allows the by-pass of some onerous steps in the current Italian plastic waste management system, which involves a great deal of effort, inefficiency and costs. Anticipating the differentiation of plastic waste allows a rethinking of the integration of the supply chain after consumption, avoiding some intermediate processes (Mastellone, 2020) that reduce the sustainability of the plastic products, both environmentally due to a loss of resources at each step, and economically due to the complexity to recognise and separate mixed plastics. In particular, a well-sorted plastic flow can technically be supplied directly to the recycler, allowing a greater recovery of the resource value according to the CE paradigm. This new (circular) model was proposed for the initiative. However, the assessment of the environmental and economic sustainability of this model was an objective of the project to confirm, improve or reject the initiative.

To drive the change and effectively implement the new model to manage the plastic waste of a sports event, all the necessary stakeholders to implement the initiative must be engaged, as proposed by Mendoza et al. (2019), to consider multiple perspectives, constraints and needs. For the *#CORRIPULITO* project, this sub-action required the involvement of all the partners necessary to cover each stage of the single-use plastic product life cycle. In particular, the partners involved in the project and their role is described in Fig. 2 and in Table 3. All the partners have been chosen from within the Emilia-Romagna region (Italy) to exploit the benefits of an initiative on a regional scale, considering also logistical aspects. Moreover, it was possible to select a plastic manufacturer who is also the owner of a plastic recycling plant.

The actions taken in this first phase allowed for the collection of all the information necessary for the design of the procedures, the equipment and the resources for the project. Moreover, all the elements necessary to quantify the sustainability were prepared. There are six main inputs for the design phase:

(i) Types and quantities of all the plastics available for their potential distribution during the event (e.g. bottles; tableware; packaging; gadgets).
(ii) Distribution of the materials: number and location of the start, refreshment points and finish line; numbers of bystanders at each point; types of distributed plastic materials.
(iii) Participants (athletes and walkers) behaviours with regards to waste collection and separation before, during and after the race.
(iv) Legal procedures to manage waste in the current system.
(v) Indications to prepare plastic waste to foster recycling.
(vi) Tools to assess the environmental, economic and social sustainability of the initiative.

According to the combination of the input information represented in Fig. 3, there are six main outputs:

a. Definition of the plastic waste collecting points: types of bins (and rubbish bags) to separately collect different plastics; number of bins (and rubbish bags) for each typology and for each refreshment point.
b. Number of volunteers to be engaged and their distribution at the collecting points.
c. Definition of effective communication to properly involve the participants (press conference and release before the event; communication panels to explain the initiative; appealing graphics for the collection points).
d. Elaboration of a procedure for the reverse logistics to send the collected plastic waste (after the event) to the proper destination, preferring the recycling plant involved in the project: types of plastics sent directly to recycler; types of plastics following the current waste management system and related procedures.
e. Selection of KPIs, relevant for the context, to assess environmental, economic and social sustainability. The selected KPIs are described in the following paragraphs.
f. Elaboration of the procedures to collect data necessary for the sustainability assessment according to the frameworks of the assessment tools and the selected KPIs.

2.1.1. KPIs for environmental sustainability

Three KPIs able to describe the efficiency of the entire management of plastic waste during the sport event were selected to assess environmental sustainability of the initiative.

1. The first is a collection efficiency (η_C) of the initiative that is expressed as in Equation (14):

$$\eta_{C\ \#CORRIPULITO}(\%) = \left(\frac{W_{collected\ plastics}}{W_{distributed\ plastics}}\right)\cdot 100 \tag{14}$$

Table 2
Quantitative characteristics of the event “Maratona Alzheimer” (VIII Edition).

Critical issue	Quantitative information
Complex organisation	• 3 competitive running races: marathon (42 km); 30 km; half-marathon (21 km). • 4 non-competitive walking races: 16 km; 2 × 10 km; 8 km.
Wide variety and number of participants	• 2140 competitive athletes. • 5000 non-competitive walkers. • About 10,000 people at the finish line (considering also spectators and volunteers).
Track	• Outdoor and open track: from the hilly to maritime landscapes of the Emilia-Romagna region and 5 municipalities crossed by the event. • 5 starting points; 9 refreshment points for runners; 4 refreshment points for walkers; 1 big and common finish line with lunch.
Short timeslot	1 day.

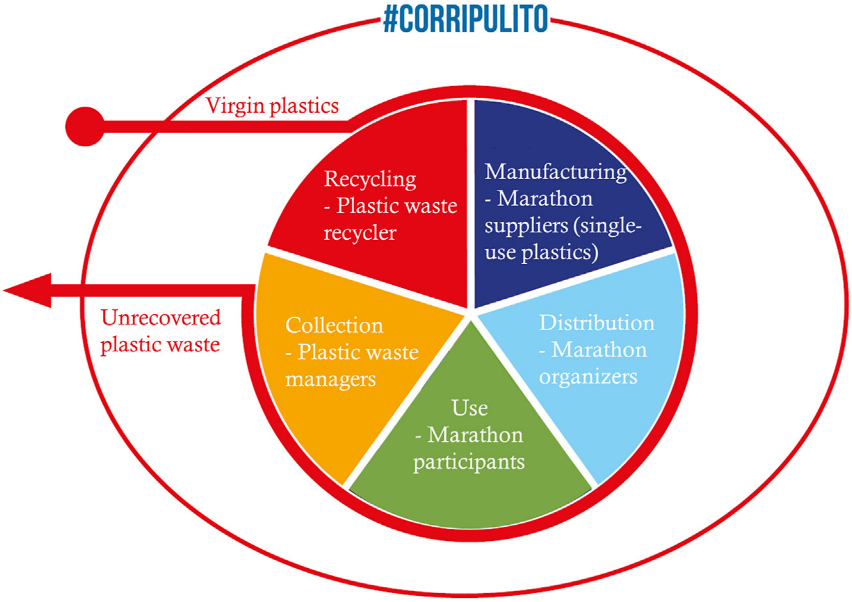


Fig. 2. Partners engaged in the circular initiative regarding plastic waste management at sports events.

Table 3
Roles of partners in the circular initiatives #CORRIPULITO.

Partner	Role in the circular initiative *#CORRIPULITO*
#CORRIPULITO team	Composed of 3 partners: • University of Bologna for the design, management and assessment of the initiative; • Romagna Iniziative for the communication of the initiative and the procurement of resources (equipment, logistic activities and volunteers); • Maratona Alzheimer for stakeholders' involvement and data provision.
Single-use plastic manufacturers	Supply of the single-use plastic products and sharing of the information about quantities for each plastic material for the marathon.
Marathon organisers	Distribution of single-use plastic products at refreshment points and information for participants about the initiatives (before and during the event).
Participants	Direct involvement in the correct collection and separation of plastic waste along the route of the race.
Waste managers	Collection and management of separated plastic waste.
Plastic recyclers	Recycling of plastic waste collected during the marathon and provision of data.

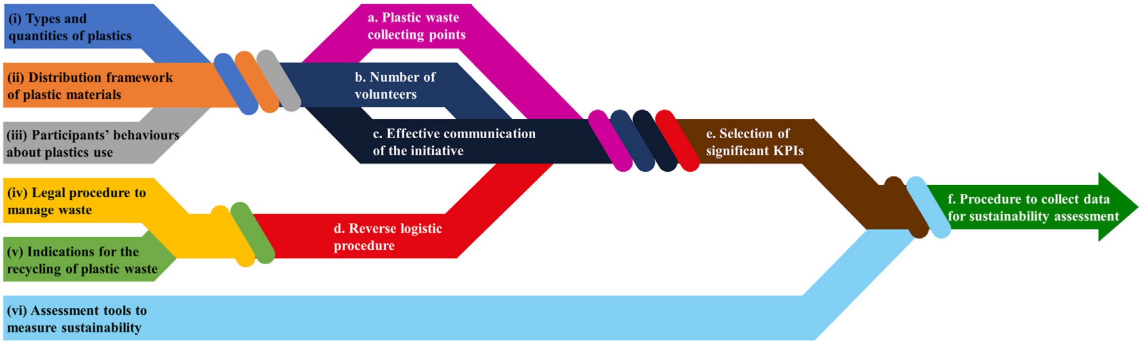


Fig. 3. Diagram of input and output for the design of the circular initiative regarding plastic management at sports events.

where $W_{collected\ plastics}$ is the quantity (kg) of plastics collected (and sorted) during the initiative (Eq. (6)) and $W_{distributed\ plastics}$ is the quantity (kg) of plastics distributed to participants during the event (Eq. (1)).

2. The second KPI is the recycling rate (RR - %) that represents the part of distributed plastics that was effectively recycled ($W_{recycled\ plastics}$ – kg – derived from Eq. (10)), as in Equation (15):

$$RR_{\#CORRIPULITO}(\%) = \left(\frac{W_{recycled\ plastics}}{W_{distributed\ plastics}}\right) \cdot 100. \tag{15}$$

3. The third KPI is the landfill rate (LR - %) that represents the part of waste that was sent to landfill ($W_{landfilled\ waste}$ − kg − Eq. (12)) in comparison to the distributed quantity, as in Equation (16):

$$LR_{\#CORRIPULITO}(\%) = \left(\frac{W_{landfilled\ waste}}{W_{distributed\ plastics}}\right) \cdot 100. \tag{16}$$

2.1.2. KPIs for economic sustainability

To evaluate the economic sustainability, the following condition of cost-effectiveness was set as KPI: An initiative such as *#CORRIPULITO* is economically sustainable if, considering the collection, sorting and recycling efficiencies obtained with the proposed model, the price of virgin plastics is greater than the unit cost of the initiative. Equation (17) must be verified for each polymer i, since it differs in management procedures, efficiencies and costs:

$$p_{virgin\ plastic_i} > \frac{W_{plastics\ sent\ to\ recycling_i} \cdot C_{recycling} + W_{GROSS\ collected\ plastics_i} \cdot \left(C_{logistic} + C_{collection}\right)}{W_{recycled\ plastics_i}} \tag{17}$$

where $p_{virgin\ plastic_i}$ is the price of virgin polymer i (€/kg); $W_{plastics\ sent\ torecycling_i}$ is the quantity (kg) of polymer i sent to the recycling plant that directly depends on the sorting efficiency; $C_{recycling}$ is the unit cost to recycle plastic waste (€/kg); $W_{GROSS\ collected\ plastics_i}$ is the gross quantity (kg) of collected plastics, sorted by polymer i, that directly depends on the collecting efficiency; $C_{logistic}$ is the unit cost to transport the plastic waste from the event location to the recycling plant (€/kg); $C_{collection}$ is the unit cost to collect the plastic waste during the sports event (€/kg); and $W_{recycled\ plastics_i}$ is the quantity (kg) of recycled polymer i, which directly depends on recycling efficiency.

2.1.3. KPIs for social sustainability

With regard to social sustainability, the aim is to identify the social impact provided not from the sport event in general, but from the specific circular initiative implemented at the sports event. Due to the absolute novelty of the initiative, the aim was to assess how the participants were directly engaged in the circular initiative and to understand their perception of the necessity to implement environmentally sustainable actions. Transferring the definitions of customer engagement, provided in Chuah et al. (2020), assimilating sports event participants to the customers of the organisation, participant engagement refers to the participants' state of mind linked to their motivations and the context that determines their direct involvement in the initiative with different levels of cognitive, emotional and behavioural activities. The participants' engagement is measured in relation to their sustainable behaviour, which, according to Chuah et al. (2020), is the "obligation" to participate in sustainable actions, which in this specific case are linked to environmental sustainability and particularly to the recycling of plastic waste at a marathon. To measure the social impact in terms of participant engagement, a typical approach is to use a survey and develop qualitative answers using a Likert scale (Abbas et al., 2018; Chuah et al., 2020; Gligor et al., 2019). The same method was used for the *#CORRIPULITO* project.

To evaluate the social sustainability as engagement of the participants in the model, three specific questions about the *#CORRIPULITO* initiative were added to a questionnaire, typically prepared by marathon organisers and distributed among runners and walkers, with the aim of understanding the perceptions of the initiative. The three *#CORRIPULITO* questions for the survey were:

S1: how do you evaluate the collection and sorting activities of waste related to *#CORRIPULITO*?
S2: with the help of *#CORRIPULITO* volunteers, was it easy to sort waste/resources?
S3: how likely do you think a project such as *#CORRIPULITO* is going to be useful to ensure the environmental sustainability of sports events?

Other indicators related to the impact of CE initiatives on customers/participants were collected by Yadav et al. (2020) and refer to: (i) the education of participants for CE practices and its benefits; (ii) the understanding of participants' requirements through social media and big data analytics; and (iii) the redesign of the initiative in relation to participants' feedback (as addressed by *S1*). To quantitatively measure these indicators, a proper method to collect information from participants must be designed with the event organisers, since a survey may not be the proper approach.

Other indicators of social sustainability are related to the role of volunteers dedicated to the circular initiative. Specific sports event volunteer motivations were investigated by Kim et al. (2018) in relation to socio-demographic characteristics, volunteering-related experiences and sports event typology, and they may be indicators of community involvement, societal values and needs, and career orientation (Kristiansen et al., 2015; Lee et al., 2016).

2.2. Practical implementation of circular initiatives at sports events (DO)

Previous papers in the literature refer to the implementation of circular principles and/or practical steps towards CE and sustainability. However, they are mainly focused on the identification, simulation and prioritisation of circular initiatives according to their potential in addressing defined objectives and goals, without providing effective practical steps during the implementation of the initiatives. For example, Konietzko et al. (2020) provide a methodology to define recommended principles matching an initial pattern matching template with empirical data from case studies: in the experimentation phase the authors refer to a prototype and test the circular ecosystem without specifying practical steps necessary for these actions. Pieroni et al. (2020) propose to shift from CE theory to practice through a method for evaluating the application of circular archetypes with the aim to generate ideas, identify opportunities and prioritise circular business models. Klenk et al. (2020) use an approach based on simulation and continuous improvement to take a decision about the implementation of the optimal circular strategy, but they do not describe any practical implementation or its steps. Moktadir et al. (2020) propose the application in practice of a decision support tool to assess the challenges to CE practices in the leather industry, but details about the implementation are not provided. In this paper, the authors intend to provide a practical implementation of a circular initiative about plastic management at sports events, according to the literal meaning of the term, that is the execution: the act of providing practical and actual activities for accomplishing the designed initiative framework.

Following this intention, the practical implementation of the *#CORRIPULITO* initiative is described. It covers all the temporal stages (before, during and after the event).

Before the event it was necessary to prepare the resources dedicated to the project. This means: (i) to manage the procurement of the equipment designed during the previous stage (bins, rubbish bags, T-shirt for volunteers and communication panels with the selected graphics); and (ii) to train the people dedicated to the project, ensuring their support for the collection and the separation of plastics waste by participants. The bins were studied to make it easy to recognise the proper location of plastic waste and its disposal, even for runners who could not 'waste time' during the race. For this reason, some bins were equipped with a basket structure to encourage the throwing of plastic waste by athletes while running. Finally, a proper communication campaign was launched to inform participants about the initiative in which they would be directly involved. Fig. 4 shows the structure of bins, baskets and communication panels used for the initiative. The equipment was constructed in paper to be fully recycled due to the experimental character of the project.

During the day of the event, the practical implementation phase required: (i) the preparation of the collecting points (as designed) and (ii) the management of the collection and separation of plastic waste, always supported by the communication of the objectives of the project by volunteers. A reference person among volunteers was appointed for each collecting point. This person was equipped with a kit consisting of: a specific number of bins and rubbish bags sorted in relation to the type of service point (start, refreshment, finish line); labels for rubbish bags to differentiate their content (different type of waste); electronic scales to weigh the filled bags after their use; a "handbook" with clear instructions for the proper separation of waste; and two forms to fill in, indicating the number of used rubbish bags for each plastic material and their weight. The manager had to coordinate their team in the following activities:

1. Positioning the bins in a specific area close to the refreshment point. In case of refreshment for runners, the specific positioning of the bins and baskets was studied based on the analysis of athlete behaviour during the race, as represented in Fig. 5.
2. Preparing the rubbish bag by putting the correct label on it to ensure the contents were differentiated and prepared for the corresponding bin.
3. Weighing the full rubbish bags and inserting some data on the label (number of the bag and weight).
4. Maintaining the separation of full rubbish bags in a service area to speed up the collection and separation of bags by the waste manager at the end of the event.
5. Filling in the forms with required data, i.e. the number of the bags with the corresponding weight written in the column related to the specific content (type of plastics).

Fig. 6 shows the main practical activities to be conducted during the event.

On the same day, the involved waste manager collected the prepared full rubbish bags (see Fig. 6c), maintaining the separation both on the truck and at the waste management plant.

Finally, after the day of the event, the collected waste was sent to the proper destination, preferring the recycling plant involved in the project: with the preferred option, a truck authorised to transport waste was used that issued the waste identification form.

2.3. Assessment of the sustainability of circular initiatives at sports events (CHECK)

The assessment of the initiative was performed through the application of two different tools: (i) the application of an innovative visualisation tool for circular business models and initiatives (Bianchini et al., 2019); and (ii) a questionnaire for participants. This approach allows the collection of data required to evaluate the selected KPIs, enables the representation of the effectiveness of the initiative and allows practitioners to be supported to improve and replicate it in other similar contexts.

2.3.1. Application of the visualisation tool for circular initiatives

For the assessment of the sustainability of the initiative *#CORRIPULITO*, the visualisation tool, developed by the Department of Industrial Engineering at the University of Bologna and described in detail in Bianchini et al. (2019), was used. It was defined to measure and visualise a circular business model, but, due to its flexibility, it is suitable to also be adapted to the described initiative, considering each partner as a specific stage in the value chain. The setting of the

#CORRIPULITO

FAI CENTRO CON NOI

contribuisci ad una corretta raccolta di rifiuti/risorse durante la Maratona.

Il progetto #CORRIPULITO ha come obiettivo l'ottimizzazione della gestione dei rifiuti plastici prodotti durante la Maratona Alzheimer, attraverso una pratica implementazione di Economia Circolare.

La plastica distribuita ai partecipanti verrà opportunamente raccolta e inviata a impianti riciclatori, che utilizzeranno il materiale recuperato per realizzare altri prodotti plastici, recuperando l'intero valore della risorsa.

La circolarità, l'impatto ambientale e la sostenibilità economica del progetto #CORRIPULITO verranno quantificati attraverso uno studio condotto dal laboratorio TAILOR (Dipartimento di Ingegneria Industriale - Università di Bologna).

Fig. 4. Equipment and the communication panels for the collection of plastic waste during the initiative *#CORRIPULITO*.

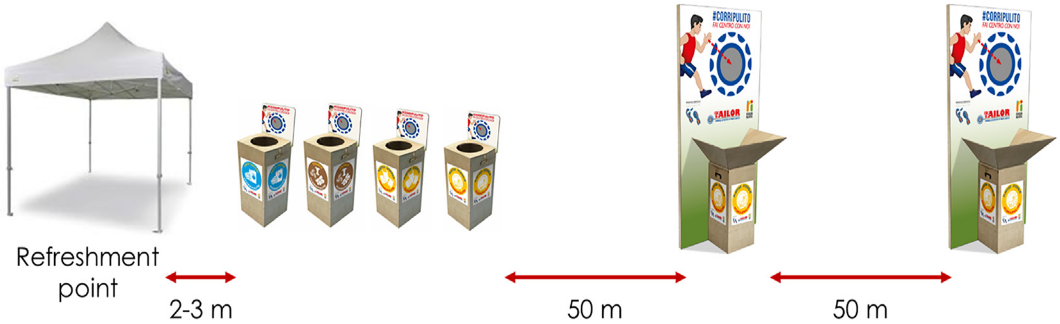


Fig. 5. Location of bins to facilitate plastic collection by runners.

N° sacco	Plastica posate - kg	Plastica stoviglie - kg	Plastica bottiglie - kg	Plastica generica - kg	Carta - kg	Organico - kg
5		1,440				
6		0,900				
7		1,265				
8		1,430				
9		1,040				
10		1,435				
11		1,485				
12		1,355				
13		1,170				
14				1,080		
15		0,530				
16				0,720		
17					0,165	
18						3,170

Fig. 6. Representation of the activities of the procedure to conduct during the practical implementation of the *#CORRIPULITO* initiative: a. pasting the label on rubbish bags describing the material contained; identifying number and weight as information; b; weighing the bag after use; c. separation of full bags by content; d. filling in forms.

tool to describe the *#CORRIPULITO* initiative allows the provision of quantitative information to evaluate specific environmental KPIs and to be associated with costs for the measurement of economic sustainability.

In this case, the material flows are measured in kg of plastics (sorted by polymer), and consequently the height of the blocks are proportional to this quantity. The tool was applied to compare the results of the initiative to the scenario of the previous editions of the same event. With this aim, the main stages that must be assessed and the relative data to collect are summarised in Table 4.

Table 4
Data from each partner to be analysed to assess the sustainability of the initiative.

Stage	Necessary data and analysis
Marathon – Distribution	1. Plastics quantity available for the event (provided by suppliers), sorted by polymer (kg). 2. Plastics quantity effectively distributed to participants, sorted by polymer (kg).
Participants – Use	Not available
#CORRIPULITO– Collection and sorting	3. Plastics quantity collected by #CORRIPULITO initiative (kg). 4. Average increase rate of weight of dirty plastic products in comparison to clean ones (%).
Waste managers – Collection, sorting and reverse logistics	5. Unit costs for plastic collection (€/kg). 6. Unit cost for waste transport to recycling plant (€/kg). 7. Efficiency of plastic sorting in the current waste management system (%). 8. End-of-life of unrecoverable plastics.
Recycler – Recycling	9. Efficiency of plastic recycling (%). 10. Unit costs for plastic recycling (€/kg). 11. End-of-life of unrecycled plastics (process waste).

The methodology used for collecting each of the listed pieces of data is explained in detail.

2.3.1.1. Marathon – distribution

1. The single quantities (kg) for each plastic material available for the event was measured, analysing the supplies by providers (direct suppliers of single-use plastics or suppliers of products packed with plastics). Where weight was not available, the total weight was determined considering the quantity (number of items) and the unit weight of the plastic component. The sum of these quantities determined the total quantity of plastics that was available for the participants ($W_{available\ plastics}$ - kg).

2. The total available quantity of plastics could not correspond to the actual quantity of used plastics. The quantities of plastics effectively distributed to the participants was measured counting the number of unused plastic products and then by multiplying their unit weight. The difference between the previous quantities ($W_{available\ plastics}$ - kg) and these quantities ($W_{unused\ plastics}$ - kg) represents the plastics used at the event ($W_{distributed\ plastics}$ - kg), as in Equation (1).

$$W_{distributed\ plastics} = W_{available\ plastics} - W_{unused\ plastics}. \tag{1}$$

2.3.1.2. Participants – use. It was not possible to collect data about waste from participants. In events like the one selected here, it is not feasible to trace the plastics after use and, even if the typology of plastics (mainly single-use plastics) suggests that all the used plastics became waste in the short term, it is not possible to respond to the following questions:

Q1. Did the entire quantity of used plastics become waste on the day and in the area of the marathon?
Q2. Was the entire quantity of used plastics disposed of in *#CORRIPULITO* bins?
Q3. Have the participants and/or volunteers added to the amount of plastics with products brought from home?

However, even if the traceability is lost in this phase, weighing the collected waste allowed the information about plastics to be recovered in the following stage.

2.3.1.3. #CORRIPULITO – collection and sorting

3. The total quantity of plastics (sorted by typology) collected during the initiative was evaluated, summing the single quantities registered in the forms by the managers of the collecting points ($W_{GROSS\ collected\ plastics}$ – kg). The sum was reduced by the weight of the rubbish bags, that was counted on the same form, to obtain the net quantity of collected plastics ($W_{NET\ collected\ plastics}$ – kg), according to Equation (2).

$$W_{NET\ collected\ plastics} = W_{GROSS\ collected\ plastics} - \#_{rubbish\ bags} \cdot w_{rubbish\ bag} \tag{2}$$

where $\#_{rubbish\ bags}$ is the total number of rubbish bags used to collect plastics and $w_{rubbish\ bag}$ (kg/rubbish bag) is the unit weight of a rubbish bag.

4. One of the main issues in the assessment phase was related to the determination of the clean weight of the collected plastics, intended as the weight of the same number and typology of the collected plastic products when they are clean. In fact, after the use, plastic products result dirty due to the beverage of food that they contained. Consequently, their weight is conceivably greater than the correspondent clean weight and an average increase of waste weight should be considered. It is plausible to think that the average increase in weight varies, not with the polymer, but with the typologies of plastic product (e.g. bottles, plates, cups, cutlery). However, since the plastics were sorted by polymer, the average increase in weight ($\overline{I_{wi}}$) is assumed to be due generic polymer i that can include one of more types of plastic products.

Since it was not possible to count the total number of plastic products collected as waste, in order to determine the average increase of weight for each polymer ($\overline{I_{wi}}$) a sample of three rubbish bags containing n types of plastic products, made with polymer i, was checked. In particular, the sampled bags (S_j with $j = 1, 2, 3$) were opened, and the waste content was counted. Having the typology (k) and the number ($\#_{\ product\ type\ k}$) of the plastic products, it was possible to obtain the correspondent clean weight (W_{cleanS_j}) of the content of the sampled bag (S_j) by considering the unit weight of the respective product ($w_{clean\ product\ type\ k}$ – kg/piece), as in Equation (3):

$$W_{cleanS_j} = \sum_{k=1}^{n} \#_{\ product\ type\ k} \cdot w_{clean\ product\ type\ k}. \tag{3}$$

The increase in weight (%) referred to the generic rubbish bag S_j is derived from Equation (4):

$$\overline{I_{wS_j}}(\%) = \left(\frac{W_{dirty\,S_j} - W_{clean\,S_j}}{W_{clean\,S_j}}\right)\cdot 100 \tag{4}$$

where S_j is a casually sampled rubbish bag containing plastic products made with polymer i, sorted in a single flow; $\overline{I_{wS_j}}(\%)$ is the rate of average increase in weight of the considered rubbish bag; $W_{clean\,S_j}$ (kg) is the weight of the content of plastics when it is clean (not used), and $W_{dirty\,S_j}$ (kg) is the weight of the same quantity and typology of plastics when dirty (after use). $W_{dirty\,S_j}$ correspond to the net weight of the considered rubbish bags ($W_{NET\ collected\ plastics\,S_j}$) derived from the form compiled by the collecting point manager.

The average increase in weight referred to the polymer i ($\overline{I_{wi}}$) was assumed as the arithmetic mean of the values obtained from the three sampled bags.

It derives that the net weight of collected plastics sorted by polymer ($W_{NET\ collected\ plastics\,i}$) must be corrected considering the corresponding ($\overline{I_{wi}}$) that returns the clean weight of each collected and sorted plastic flow ($W_{clean\,i}$ – kg), as in Equation (5):

$$W_{clean\,i} = \frac{W_{NET\ collected\ plastics\,i}}{1-\left(\overline{I_{wi}}/100\right)}. \tag{5}$$

The total quantity of collected plastics ($W_{collected\ plastics}$ - kg) is the sum of the clean weights of the flows collected and sorted by polymer ($W_{clean\,i}$). Having m types of polymer, $W_{collected\ plastics}$ is expressed as in Equation (6):

$$W_{collected\ plastics} = \sum_{i=1}^{m} W_{clean\,i}. \tag{6}$$

2.3.1.4. Waste managers – collection, sorting and reverse logistics

5. From a legislative point of view, waste can only be moved by authorised entities, which are typically multi-utilities. Consequently, the collection of the filled rubbish bags was conducted by a waste manager, also in the case of *#CORRIPULITO* model. The unit cost to collect plastics must be assessed to measure the economic sustainability of the initiative ($C_{collection}$ - €/tonne). This data was derived from the involved waste manager. However, to break away from the single plants, data from literature was considered for the economic evaluation, considering the industrial scale (Conte et al., 2018; ISPRA – 2018 data). In general, when costs were evaluated to determine economic sustainability, the actual costs for the #CORRIPULITO initiative were not considered, since they were not really meaningful (since associated to an experimentation). Consequently, it was more suitable to consider costs on an industrial scale.

6. For the flows of sorted plastics that were sent directly to the recycler (the recycling plant of the involved partner can treat only specific polymers), the unit cost to transport the separated plastics directly from the event location to the recycler must be considered to assess the economic sustainability of the event. Also in this case, the cost was considered on an industrial scale ($C_{logistic}$ - €/tonne), which depends on the distance and the transported weight.

7. The flows of sorted plastics that were not directly sent to recycler were managed following the current waste system. For the assessment, sorting efficiency for each polymer ($\eta_{sorting\,i}$ with i generic polymer - %) is necessary to understand the quantity of recognised plastics sent to a recycler. Equation (7) provide this parameter for each polymer i:

$$\eta_{sorting\,i}(\%) = \frac{W_{plastics\ sent\ to\ recycling\,i}}{W_{NET\ collected\ plastics\,i}}\cdot 100 \tag{7}$$

where $W_{plastics\ sent\ to\ recycling\,i}$ (kg) is the polymer recognised by the sorting plant that constitutes the output to be sent to recycler, while $W_{NET\ collected\ plastics\,i}$ (kg) is the input flow for the sorting plant and constitutes the flow of collected plastics, sorted by polymer *i*.

Since the involved waste manager does not have data that relates to the efficiency of selection and sorting of the single plastic polymers, data from literature was used (Conte et al., 2018). In this reference, the sorting efficiency is expressed for each plastic polymer and considers the two stages of sorting that occur in the Italian plastic waste management system, determining the quantity that is sent to the recycler.

Knowing the value of $\eta_{sorting\,i}$, it is possible to identify the quantity $W_{plastics\ sent\ to\ recycling\,i}$: it corresponds to $W_{NET\ collected\ plastics\,i}$ for the sorted polymer that can be sent directly to the recycler (it means that, for these polymers, $\eta_{sorting\,i} = 1$, since the sorting phase was conducted by participants, supported by dedicated volunteers, during the event), while it derives from Equation (7) with the use of the proper $\eta_{sorting\,i}$ for plastic flows that follow the current system of waste management.

8. Finally, information about the flows related to unrecycled plastics was collected ($W_{sorting\ waste\,i}$). In particular, the end-of-life of plastic waste that cannot be recycled is managed by a Italian consortium which, in relation to the geographical proximity of the sorting plants, encourages incineration with energy recovery or, as a last option, decides to send the waste to landfill if the logistics to reach the incinerator are more complex (COREPLA, 2018). The waste stream of the sorting stage is provided by Equation (8):

$$W_{sorting\,waste\,i} = W_{NET\,collected\,plastics\,i}\cdot\left(1-\eta_{sorting\,i}/100\right) = W_{sorting\,ER\,i} + W_{sorting\,L\,i}. \tag{8}$$

where $W_{sorting\ ER\,i}$ (kg) is the part of the sorting waste stream sent to energy recovery, while $W_{sorting\ L\,i}$ (kg) is the part sent to landfill. Both of them or only one of these flows can be present.

2.3.1.5. Recycler – recycling

9. The recycling efficiency ($\eta_{recycling\,i}$ with i generic polymer - %) is the ratio between the output flow of recycled plastic in flakes ($W_{recycled\ plastics\,i}$ - kg) and the input flow of plastic waste that enters the plant ($W_{plastics\ sent\ to\ recycling\,i}$ - kg). The differences between these two flows are related to the presence of some “contaminants” in the input flow as described in Equation (9): remaining content residues ($\overline{I_{wi}}$); other plastics that can be treat and separated in the process ($\%_{other\ plastics\,i}$); errors in recognising good plastics; and the presence of undesired objects (other non-treated polymers or materials - e.g. paper, aluminium) ($\%_{error\,i}$) and fine plastics derived from the process that cannot be reused to manufacture new products ($\%_{fine\ plastics\,i}$).

$$\eta_{recycling_i}(\%) = \frac{W_{recycled\ plastics_i}}{W_{plastics\ sent\ to\ recycling_i}} \cdot 100 = \left(100 - \overline{I_{wi}} - \%_{other\ plastics_i} - \%_{error\,i} - \%_{fine\ plastics_i}\right). \tag{9}$$

Knowing the value of $\eta_{recycling_i}$, it is possible to identify the quantity $W_{recycled\ plastics_i}$. The total quantity of recycled plastics is (Equation (10)):

$$W_{recycled\ plastics} = \sum_{i=1}^{m} W_{recycled\ plastics_i}. \tag{10}$$

10. The unit cost ($C_{recycling}$ - €/tonne) for the recycling process was collected by the involved partner, but, for the same reason as that of the waste manager, literature data was used (Replay Plastics). Data on an industrial scale was considered.
11. Similarly to the waste manager, the end of the waste flow (the part of the input flow that does not become recycled plastic - $W_{recycling\ waste_i}$) is decided by the Italian consortium. The preferred solution is the preparation of this waste to become fuel for the cement industry. The waste stream of the recycling stage is provided by Equation (11):

$$W_{recycling\ waste_i} = W_{plastics\ sent\ to\ recycling_i} \cdot \left(1 - \eta_{recycling_i}/100\right) = W_{recycling\ ERi} + W_{recycling\ Li}. \tag{11}$$

where $W_{recycling\ ER_i}$ (kg) is the part of the recycling waste stream sent to energy recovery, while $W_{recycling\ L_i}$ (kg) is the part sent to landfill. Both of them or only one of these flows can be present.

From points 2, 8 and 11, it is possible to derive other useful quantitative information: the waste that is disposed of in landfill ($W_{landfilled\ waste}$ - kg). This parameter considers the following flows: (i) the uncollected quantity of plastics distributed during the event (the difference between the distributed quantity and the collected quantity) assumed as landfilled, that corresponds to the worst case in the waste hierarchy; (ii) the ash residues derived by the incineration of the flows sent to energy recovery plants; and (iii) the waste streams of the sorting and recycling plants that, according to the Italian consortium, are disposed of in landfill. This results from Equation (12):

$$W_{landfilled\,waste} = \left(W_{distributed\,plastics} - W_{collected\,plastics}\right) + \%_{ash\,residues} \cdot \left(\sum_{i=1}^{m} W_{sorting\,ER_i} + \sum_{i=1}^{m} W_{recycling\,ER_i}\right) + \left(\sum_{i=1}^{m} W_{sorting\,L_i} + \sum_{i=1}^{m} W_{recycling\,L_i}\right) \tag{12}$$

where $\%_{ash\ residues}$ is the rate of ash residues from incineration process.

Finally, this also results in the evaluation of the energy recovery (ER - MJ), as in Equation (13):

$$ER = k_i \cdot \left(\sum_{i=1}^{m} W_{sorting\ ER_i} + \sum_{i=1}^{m} W_{recycling\ ER_i}\right) \tag{13}$$

where k_i (MJ/kg) is the lower heating value of the waste streams sent to energy recovery, taken as a constant value for all flows, since it is a mixture of residues, mixed plastics and foreign objects.

2.3.2. Administration of a questionnaire to participants

The three questions to assess the social sustainability were added in the typical survey prepared by marathon organisers to evaluate the satisfaction of the runners and walkers and improve the next editions according to their opinions. For each of these questions, the respondents could choose a number from 1 (minimum value – very low) to 10 (maximum value – very high). The survey was sent through the marathon newsletter and sponsored on the social channels for a week after the racing. Some 149 runners and 115 walkers responded to the questionnaire.

3. Results

The application of the proposed model and methodology to the sports event “Maratona Alzheimer” determined the sorting of plastics into four typologies. They were sorted by polymer, but to simplify the activity, conducted by participants with the support and the indications of dedicated volunteers, the types of plastic products were used as sorting categories since this was easier to be recognised by participants. All the outputs of the design phase are summarised in Table 5.

After the collection of rubbish bags along the route of the race, the areas around the refreshment/collecting points and the surroundings were completely clean.

The quantification of the results, obtained by the design and implementation of the *#CORRIPULITO* initiative, derived from the

Table 5
Main outputs of the design procedure proposed for the initiative.

Parameter	*#CORRUPILITO* application
Types of sorted plastics	• PET – bottles; • PP – plates and cups; • PS – cutlery; • MIX – other plastics.

Collecting points	• 19 collecting points;
	• Types of bins at each type of collecting point:[a]
	  • at starting line and refreshment points for walkers: 1 bin for PET – bottles; 1 bin for PP – plates and cups; 1 bin for MIX – other plastics;
	  • for refreshment points for runners: 1 bin for PP – plates and cups; 2 basket bins for PP – plates and cups; 1 bin for MIX – other plastics;
	  • for finish line: 2 bins for PET – bottles; 2 bins for PP – plates and cups; 2 bins for PS cutlery and 2 bins for MIX – other plastics. This configuration was repeated for at five collecting points due to the great number of participants at the finish line.

Number of bins for plastic waste	109 plastic bins • 21 for PET – bottles; • 48 for PP – plates and cups; • 10 for PS – cutlery; • 30 for MIX – other plastics.
Number of volunteers	80 volunteers selected and trained for the *#CORRIPULITO* initiative and equipped with a dedicated T-shirt.
Communication	• 1 press conference (1 week before the event); • 9 communication panels located at start and finish line to describe the initiative and its objectives.
Reverse logistics	• PET – bottles: sent directly to involved recycler with authorised truck and waste form; • PP – plates and cups: sent directly to involved recycler with authorised truck and waste form; • PS – cutlery: treated within the current management system; • MIX – other plastics: treated within the current management system.

[a] Each collecting point was also equipped with 1 bin for paper, 1 bin for organic waste and 1 bin for undifferentiated waste (this last bin was selected with a lower size to highlight that only a minor part of waste cannot be sorted).

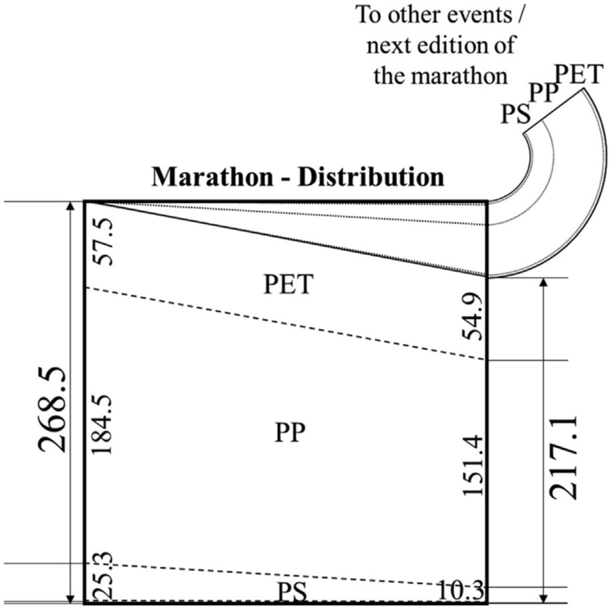


Fig. 7. Setting of the visualisation tool for the distribution stage (marathon). Input and output flows (kg of plastics) are sorted by polymer and follow different streams according to their use.

setting of the visualisation tool for each involved stage. The parameter that was considered to measure the tool stages is the quantity (kg) of plastics. The visualisation tool is fed with quantitative information collected and calculated during the entire initiative and was derived from literature and the partners involved. These values were used to evaluate the parameters in the equations and to measure the selected KPIs for sustainable assessment, as described in Paragraph 2.3 (and where possible the same numerical points were provided).

3.1. *Marathon – distribution*

1. The total quantity of plastics available for the marathon (provided by suppliers) was 268.5 kg ($W_{available\ plastics}$). It considers the plastic products that could be effectively distributed to participants during a race day, excluding: (i) plastic materials distributed in previous days/weeks (e.g. race pack, T-shirt for participants and volunteers) since they would probably not end up as waste in the area of the marathon but in participants'/volunteers' houses (ii) plastic materials used by volunteers (e.g. bottles to fill cups, larger sheets of plastic as secondary packaging for bottles and other transported products); since this material was directly not used by participants whose behaviour was one of the main investigated aspects and since the correct management of waste by volunteers was assumed; and (iii) plastic materials brought from home by participants and volunteers (e.g. additional bottles and snack packaging, packaging for food to distribute at refreshment points) since the marathon organisers are not directly responsible for this type of plastic and cannot control this flow.
2. Not all the available plastics was distributed to the participants on the day of the race. In particular, a quantity of 51.4 kg of plastics is left over ($W_{unused\ plastics}$) (and is available e.g. for other events in the territory or for the next edition of "Maratona Alzheimer"), which means that marathon volunteers actually distributed 217.1 kg of plastics ($W_{distributed\ plastics}$). Fig. 7 shows the setting of the visualisation tool developed by the University of Bologna for the marathon organisation stage, where input and output flows (kg of plastics) are expressed and sorted by polymers.

3.2. *Participants - use*

The actually distributed plastics (output of marathon – distribution stage – 217.1 kg) becomes the input flow of the box representing the participants' use. According to the arguments described in Paragraph 2.3, it is not possible to know the exact output flow of this stage. Fig. 8 shows two different scenarios regarding this flow:

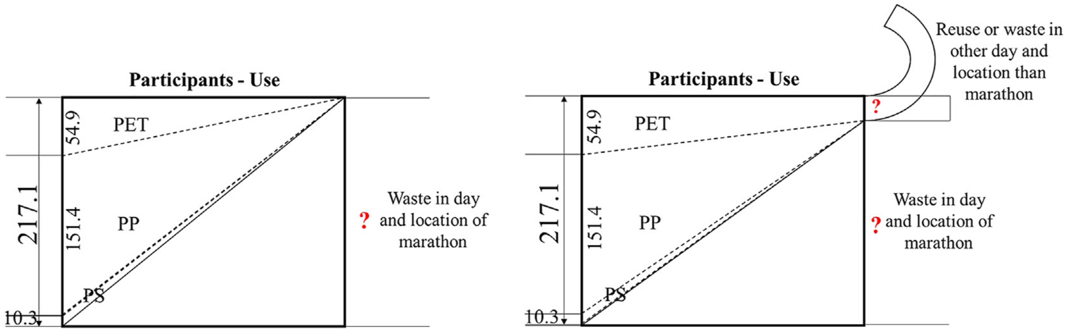


Fig. 8. Setting of the visualisation tool for the use stage (participants). Two scenarios are shown: a) all the distributed plastic products ended up as waste on the day and in the location of marathon; b) part of plastic products were reused or ended up as waste on different days and in other locations.

Table 6
Flows of distributed and collected plastics sorted by polymers.

Polymer type	Distributed plastics (kg) $W_{distributed\ plastics_i}$	Number of rubbish bags $\#_{rubbish\ bags_i}$	Gross weight of collected plastics (kg) $W_{GROSS\ collected\ plastics_i}$	Net weight of collected plastics (kg)[a] $w_{rubbish\ bag}$
PET - bottles	54.9	44	38.4	37.0
PP – plates and cups	151.4	176	165.7	160.1
PS – cutlery	10.3	12	10.7	10.3
MIX - other plastics	0.4	47	30.3	28.8
Total	217.1	279	245.2	236.2

[a] Unit weight of rubbish bags $w_{garbage\ bag} = 0.032\ kg$.

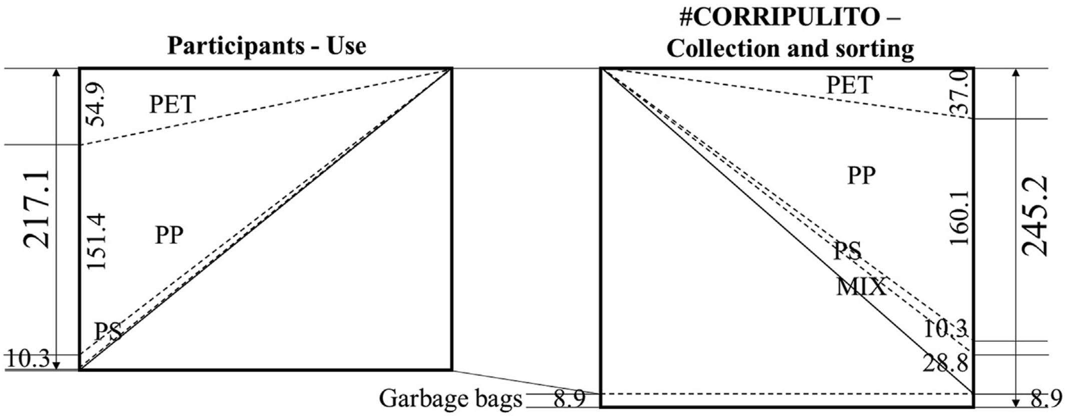


Fig. 9. Setting of the visualisation tool for the collection and sorting stage (*#CORRIPULITO*).

a) all the distributed plastics ended up as waste on the day and in the location of the event, but it is not possible to identify how much it was collected and properly sorted in *#CORRIPULITO* bins; b) the entire quantity of distributed plastics did not end up as waste, but part of this was reused (e.g. bottles) or became waste at a different time and in a different location to that of the marathon.

3.3. *#CORRIPULITO* – collection and sorting

Due to the missing data about output flow from participants' use, it is not possible to know the input flow of *#CORRIPULITO*. The traceability of plastic waste returns under control by considering the total quantity of collected plastic waste, monitored by collection point managers.

3. In total, at all of the collecting points of the *#CORRIPULITO* initiative, 279 rubbish bags ($\#_{rubbish\ bags}$) were used specifically for plastics. The sum of the weight of the 279 filled rubbish bags corresponds to the total quantity of plastics collected during the initiative: 245.2 kg (gross weight with rubbish bags - $W_{GROSS\ collected\ plastics}$). The net weight of collected plastic, eliminating the weight of the rubbish bags, is 236.2 kg ($W_{NET\ collected\ plastics}$). Table 6 contains the quantity of plastics, sorted by polymers, collected along the route of the race via the *#CORRIPULITO* initiative and compared to the quantities distributed by the marathon organisers, while Fig. 9 shows the visualisation tool for the *#CORRIPULITO* initiative linked to the participants' stage.

From this raw data it seems that, globally, the initiative collected more plastics than the distributed quantity. Even if the interception of uncounted plastic flows were plausible, the net weight of the collected plastics requires further analysis to justify these flows considering the three questions (*Q1*, *Q2* and *Q3*) analysed in the

Paragraph 2.3.

- For PET bottles the difference among the distributed and the collected quantities could be derived from the fact that bottles are products that can be easily reused or not entirely consumed on the day and in the location of the marathon (*Q1*). However, it is necessary to highlight that this flow is likely to have included plastics that were not distributed at the marathon, since some would have been brought by volunteers and participants (*Q3*).
- For PP plates and cups, the collected plastics exceed the distributed quantity. This difference (8.7 kg, about 5.7%) cannot be derived by other uncounted plastic flows, since no other PP products similar to plates and cups were used. This means that this difference is related to the residues of food and beverages in the dirty plastic.
- There is no difference between the distributed and collected weight of PS cutlery. Even though this outcome is presumably desirable, it is difficult to obtain since it means that all the cutlery became waste in the proper way without any mistakes. Also for this flow, the increase in weight of cutlery due to it having been used has to be considered.
- The great diversity between distributed and collected flows of other plastics (MIX) is related to the interception of plastics used by volunteers to pack food and beverage products, gadgets and other products for participants (*Q3*).

4. The first phase to properly correct the net weight of collected polymers is to consider the average increase in weight of dirty plastic products in comparison to clean ones ($\overline{I_{w i}}$). This parameter is known for PET bottles and it can be derived from PET bottle recycling plants, since it determines the weight lost between the input and output flows due to the quantity of liquids that remain inside the bottles and that is removed during the treatment process. This parameter was collected in the recycling plant of the involved partners: in particular, the value taken for $\overline{I_{w PET\ bottles}}$ is 7%. The same data was not available for other types of plastics. However, for PS cutlery and for other plastics (MIX), due to the typology of products and their use, the same average weight increase of the PET bottles ($\overline{I_{w PS\ cutlery}} = \overline{I_{w MIX\ other\ palstics}} = \overline{I_{w PET\ bottles}} = 7\%$) was assumed. For PP plates and cups, differences can occur in how these products are made. In fact, due to their structure, they can hold greater quantities of food and beverages. To determine their average increase in weight in comparison to the clean ones, the methodology described in Paragraph 2.3 was applied. In particular, three bags containing PP waste were opened and the waste content was counted. The results derived from this analysis are shown in Table 7.

The average weight increase for PP plates and cups ($\overline{I_{w PP\ plates\ and\ cups}}$) is obtained by the mathematical average of the three samples and it is equal to 34.3%. As expected, this value is greater than the average weight increases of other plastic products (e.g. bottles and cutlery) due to the greater quantity of food and beverage residues that were found in the rubbish bags (e.g. great quantity of water and biscuits). It can also be noted that in the sampled rubbish bags, selected by those that contained PP products, there were some PS products: in the case of cutlery, it was surely a sorting mistake due to carelessness, but in the case of coffee cups the mistake could have been the result of a wrong consideration that all cups were made of PP. This issue will be considered in Section 4 (Discussion).

According to this analysis, all the raw data corresponding to the net weight of collected plastics must be corrected with the corresponding average weight increase. The results of this correction are shown in Table 8.

This suggests that the quantity of plastics effectively collected during the *#CORRIPULITO* initiative was 190.5 kg ($W_{collected\ plastics}$). The difference is attributable to the residues of food and beverages. Fig. 10 shows the corrected version of Fig. 9.

3.4. Recycler – recycling

9. According to the reverse logistic procedure designed before the event, PET bottles and PP plates and cups were directly sent to the recycling plant of the involved partner. The recycling plant typically treats PET bottles but, due to the low quantity of PP quantity (about 120 kg), this polymer was also recycled at the same plant. The recycling plant normally ensures the separation of recycled PET from PP, that is respectively the polymer of the bottle body and of the cap. The directing of the two flows to the same plant is a specific condition of this project that cannot be repeated in other contexts or with higher quantities of plastics, but in this case it was useful to: (i) reduce logistics costs and impacts; and (ii) gain more reliable data and in a shorter time due to the direct involvement of the partner. The net weight of plastics sent

Table 7
Results of the procedure to evaluate the average increase in weight for the PP waste.

Plastic product content (***product type k***)	Sampled rubbish bags					
	$\boldsymbol{S}_1 \rightarrow$ Rubbish bag #11 (collecting point 19[a])		$\boldsymbol{S}_2 \rightarrow$ Rubbish bag #8 (collecting point 5[a])		$\boldsymbol{S}_3 \rightarrow$ Rubbish bag #4 (station 13[a])	
	Quantity (#) $\#_{product\ type\ k}$	Clean weight (kg) $\boldsymbol{W}_{clean S_1 k}$	Quantity (#) $\#_{product\ type\ k}$	Clean weight (kg) $\boldsymbol{W}_{clean S_1 k}$	Quantity (#) $\#_{product\ type\ k}$	Clean weight (kg) $\boldsymbol{W}_{clean S_1 k}$
PS – cutlery[b]	3	0.007	–	–	–	–
PP – plates[b]	19	0.304	–	–	–	–
PP – cups[b]	16	0.042	115	0.299	669	1.739
PP - beer cups[b]	18	0.108	–	–	–	–
PS - coffee cups[b]	–	–	–	–	13	0.052
Total clean weight (kg) $\boldsymbol{W}_{clean S_j}$		0.461		0.299		1.791
Total dirty weight (kg) $\boldsymbol{W}_{dirty S_j}$		0.533		0.488		2.213
Weight increase $\overline{\boldsymbol{I}_{\boldsymbol{w} S_j}}$ (%) [c]		15.6%		63.2%		24.0%

[a] Collecting point 19 → collecting point corresponding to the finish line; collecting points 5 and 13 → collecting points corresponding to a refurbishment point for runners.
[b] The unit weight (kg/piece) of the plastic products are: $w_{PS\ cutlery} = 2.35 \cdot 10^{-3}\ kg/piece$; $w_{PP\ plates} = 16 \cdot 10^{-3}\ kg/piece$; $w_{PP\ cups} = 2.6 \cdot 10^{-3}\ kg/piece$; $w_{PP\ beer\ cups} = 6 \cdot 10^{-3}\ kg/piece$; $w_{PS\ coffee\ cups} = 4 \cdot 10^{-3}\ kg/piece$.
[c] Calculated as in Equation (4).

Table 8
Correction of the plastic net weight with the average increase of weight due to food and beverage residues.

Polymer type	Net weight of collected plastics (kg) $W_{NET\ collected\ plastics_i}$	Average weight increase (%) $\overline{I_{wi}}$	Corrected weight of collected plastics (kg) $W_{clean\,i}$
PET – bottles	37.0	7.0	34.6
PP – plates and cups	160.1	34.3	119.3
PS – cutlery	10.3	7.0	9.7
MIX – other plastics	28.8	7.0	26.9
Total	236.2	–	190.5

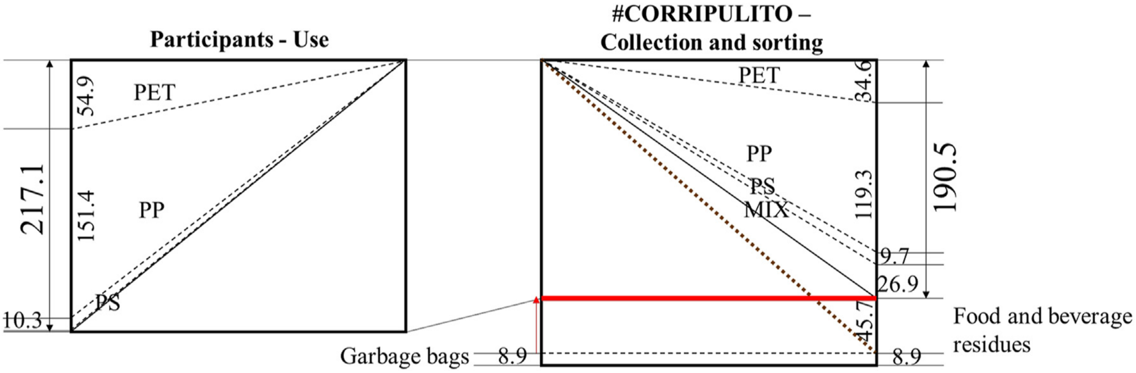


Fig. 10. Setting of the visualisation tool for the collection and sorting stage (*#CORRIPULITO*) after the correction of the net weights.

directly to the recycler was 204.1 kg (37.7 kg of PET bottles and 160.1 kg of PP plates and cups – in this case $W_{NET\ collected\ plastics_i} = W_{plastics\ sent\ to\ recycling_i}$). The recycling efficiency of PET bottles at this plant is 75% ($\eta_{recycling_{PET}}$). The remaining part consists of: (i) polyolefins (PE and PP) derived from the bottle cap and label; (ii) liquid residues and other foreign objects; (iii) sorting errors; and (iv) fine recycled plastics that cannot be remanufactured. Table 9 summarises the main parameters, calculated and collected for partners at this stage and used for the assessment. For the PP plates and cups, some parameters was considered equal to PET bottles, while there are no other plastics that can be sorted in the flow, and the amount of liquid residues was substituted by the value of the average weight increase, calculated in the project, which was 34.3% ($\overline{I_{wPP}}$). The recycling efficiency derived for PP products was 52.7% ($\eta_{recycling_{PP}}$).

11. Considering this data, the actual recycled PET was 27.7 kg ($W_{recycled\ plastics_{PET}}$), used to produce food packaging such as trays by the involved plastic manufacturer, and the actual recycled PP (and PE from bottle labels) was 100.4 kg ($W_{recycled\ plastics_{PP}}$), used to produce household cleaning sets, for example. The recycled PP quantity considers both the flow of plates and cups and the flow derived from bottles (caps and labels). The remaining quantity, 76.0 kg ($W_{recycling\ waste_{PET+PP}}$), was treated for use as fuel in the cement sector or for energy recovery (described thus: $W_{recycling\ waste_{PET+PP}} = W_{recycling\ ER_{PET+PP}}$).

3.5. Waste manager – collection, sorting and reverse logistics

7. PS cutlery and other plastics (MIX) followed the current management of plastic waste, passing from two sorting stages in two different plants, which are considered together in one stage in the visualisation tool. Currently, cutlery is sorted at the first sorting plant and is not sent to recycling but to incineration, in order to produce energy. Consequently, the entire quantity of collected PS cutlery produced energy ($W_{sorting\ waste_{PS}} = W_{sorting\ ER_{PS}} = 9.7$ kg). The other plastics (MIX), consisting mainly of flexible packaging that was smaller (smaller than an A3 sheet) are sent to the second selection plant. The total efficiency of this double sorting stage is assumed to be 24.09% ($\eta_{sorting_{MIX}}$) (Conte et al., 2018). From the entire collected quantity ($W_{NET\ collected\ plastics_{MIX}} = 26.9$ kg), 7.3 kg was sent to a recycling plant ($W_{plastics\ sent\ to\ recycling_{MIX}}$), while the rest was incinerated to produce energy ($W_{sorting\ waste_{MIX}} = W_{sorting\ ER_{MIX}} = 19.6$ kg).
8. Globally, from the four flows determining a quantity of 190.5 kg, some 135.4 kg of recycled plastics was obtained ($W_{recycled\ plastics}$). The remaining 55.1 kg was used to recover energy ($\sum_{i=1}^{m} W_{sorting\ ER_i} + \sum_{i=1}^{m} W_{recycling\ ER_i}$). In particular, considering an average lower heating value equal to 28.45 MJ/kg (k_i) (Petriglieri, 2014) for the waste streams of plastic sorting and recycling plants and an ash residue rate of 12.01% ($\%_{ash\ residues}$) (Erichsen and Hauschild, 2000), the total produced energy was 1567.0 MJ and the quantity of ash residues sent to landfill was 6.6 kg.

Fig. 11 shows the visualisation tool for waste management and recycling stages.

It is assumed that the uncollected quantity of plastics distributed during the marathon (the difference between the distributed quantity 217.1 kg and the collected quantity 190.5 kg, that is 26.6 kg: $W_{distributed\ plastics} - W_{collected\ plastics}$) was sent to landfill, which corresponds to the worst case in the waste hierarchy. With this assumption the total quantity of waste sent to landfill by the cycle implemented with the *#CORRIPULITO* initiative was 33.2 kg ($W_{landfilled\ waste}$).

The main parameters, calculated and collected from the literature and by partners and used for the assessment of the *#CORRIPULITO* initiative, are summarised in Table 9.

The parameters were used to evaluate the described KPIs to

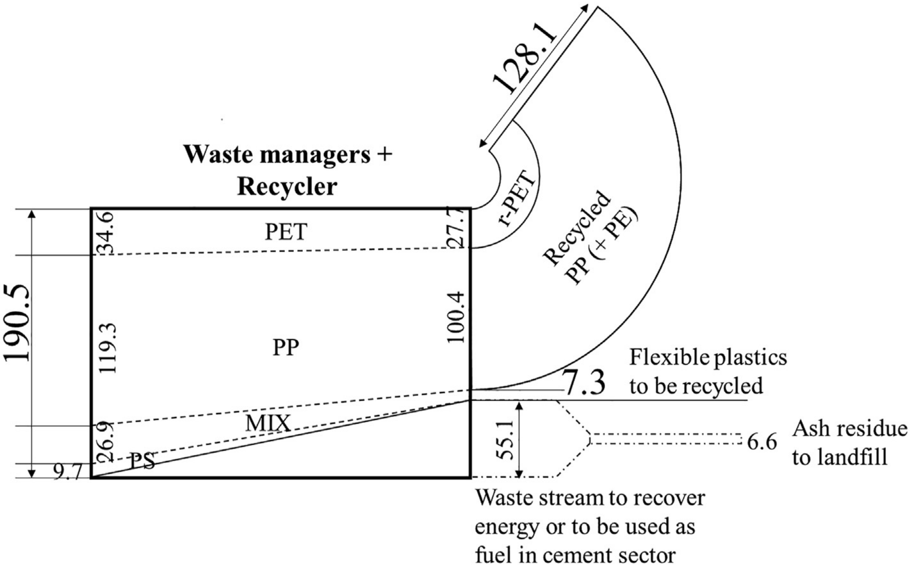


Fig. 11. Setting of the visualisation tool for the recycler and waste manager in the same stage.

Table 9
Parameters derived from literature or from partners for the environmental and economic assessment.

Stage	Parameter	Value	Source
Marathon - Distribution	• $W_{available\ plastics}$	268.5 kg	Counted
	• $W_{unused\ plastics}$	51.4 kg	Counted
	• $W_{distributed\ plastics}$	217.1 kg	Calculated (Eq. (1))
#CORRIPULITO – Collection and sorting	• $W_{GROSS\ collected\ plastics}$	245.2 kg	Weighed
	• $\#_{rubbish\ bags}$	279	Counted
	• $w_{rubbish\ bag}$	0.032 kg	Weighed
	• $W_{NET\ collected\ plastics}$	236.3 kg	Calculated (Eq. (2))
	• $\overline{I_w}_{PET} = \overline{I_w}_{PS} = \overline{I_w}_{MIX}$	7%	Partner – recycler
	• $\overline{I_w}_{PP}$	34.3%	Calculated (Eq. (4))
	• $W_{collected\ plastics}$	190.5 kg	Calculated (Eq. (6))
Waste managers - Collection, logistics and sorting	• $C_{collection}$	187.4 €/ton	Literature: (ISPRA-2018 data)
	• $C_{logistic}$	36.1 €/ton	Literature: (Azienda Servizi Ambientali (ASA))
	• $\eta_{sorting\ PET}$	61.92%	Literature: (Conte et al., 2018)
	• $\eta_{sorting\ pp}$	78.12%	Literature: Literature: (Conte et al., 2018)
	• $\eta_{sorting\ MIX}$	24.09%	Literature: (Conte et al., 2018)
	• $W_{sorting\ waste\ PS+MIX} = W_{sorting\ ER\ PS+MIX}$	29.3 kg	Calculated (Eq. (8))
Recycler – Recycling	• $\%_{other\ plastics\ PET}$	5%	Partner – recycler
	• $\%_{error\ PET} = \%_{error\ PP}$	5%	Partner – recycler
	• $\%_{fine\ plastics\ PET} = \%_{fine\ plastics\ pp}$	8%	Partner – recycler
	• $\%_{other\ plastics\ pp}$	0%	Assumed
	• $\eta_{recycling\ PET}$	75%	Partner – recycler
	• $\eta_{recycling\ pp}$	52.7%	Calculated (Eq. (9))
	• $W_{recycled\ plastics}$	135.4 kg	Calculated (Eq. (10))
	• $C_{recycling}$	520.7 €/ton	Literature: (Replay Plastics)
	• $W_{recycling\ waste\ PET+PP} = W_{recycling\ ER\ PET+PP}$	69 kg	Calculated (Eq. (11))
Energy recovery/Landfill	• $W_{uncollected\ plastics}$	26.6 kg	Calculated (Eq. (12))
	• $\%_{ash\ residues}$	12.01%	Literature: (Erichsen and Hauschild, 2000)
	• $W_{landfilled\ waste}$	33.2 kg	Calculated (Eq. (12))
	• k_i	28.45 MJ/kg	Literature: (Petriglieri, 2014)
	• ER	1567 MJ	Calculated (Eq. (13))

assess the sustainability of the initiative.

3.6. Environmental sustainability

1. The value of this KPI about collection efficiency (η_C), obtained by the initiative, is (from Eq. (14)):

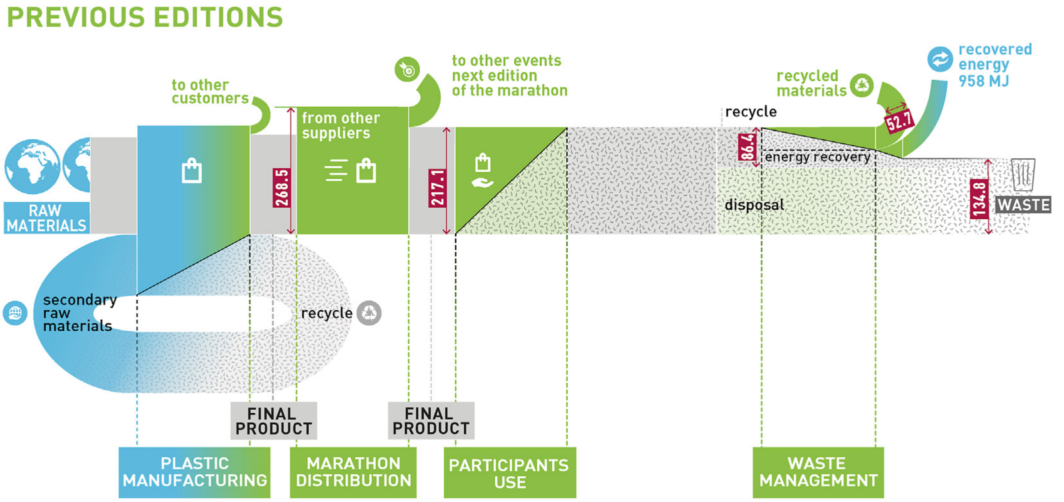
$$\eta_{C\ \#CORRIPULITO}(\%) = \left(\frac{W_{collected\ plastics}}{W_{distributed\ plastics}}\right)\cdot 100 = \left(\frac{190.5\ kg}{217.1\ kg}\right)\cdot 100 = 87.7\%$$

Table 10
Values of collected plastics and plastics sent to the recycling plant, considering "linear" waste management (previous editions).

Polymer type	Corrected weight of collected plastics (kg)	Sorting efficiency (%)	Quantity of plastics sent to recycling (kg)
PET - bottles	16.4	61.92	10.2
PP – plates and cups	51.8	78.12	40.5
PS – cutlery	9.7	discarded	0.0
MIX - other plastics	8.5	24.09	2.0

2. The recycling rate (*RR*) obtained with *#CORRIPULITO* is, as in Equation (15):

$$RR_{\#CORRIPULITO}(\%) = \left(\frac{W_{recycled\ plastics}}{W_{distributed\ plastics}}\right) \cdot 100 = \left(\frac{135.4\ kg}{217.1\ kg}\right) \cdot 100 = 62.4\%.$$



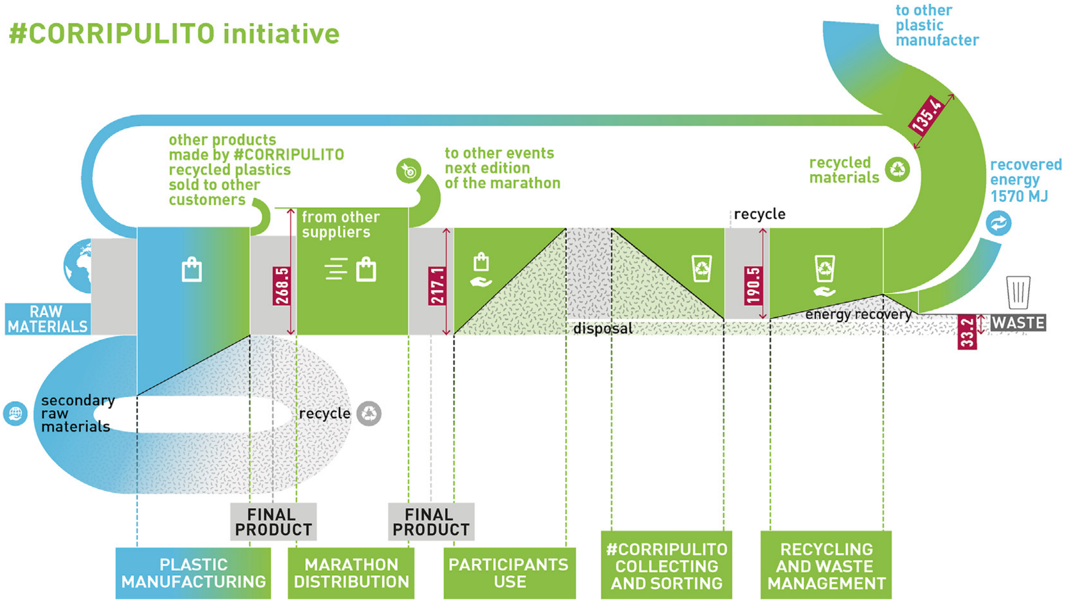


Fig. 12. Setting of the visualisation tool for all involved stages in two different scenarios: (i) upper side – previous editions of the event with differentiated collection of waste only at the finish line; (ii) lower side – entire value chain of *#CORRIPULITO*.

3. The landfilling rate (*LR*) obtained with *#CORRIPULITO* is, as in Equation (16):

$$LR_{\#CORRIPULITO}(\%) = \left(\frac{W_{landfilled\ waste}}{W_{distributed\ plastics}}\right) \cdot 100 = \left(\frac{33.2\ kg}{217.1\ kg}\right) \cdot 100 = 15.3\%.$$

The values of the selected environmental KPIs can be compared to the same parameters calculated in the case of the typical waste management of the other editions of the studied event. In the previous editions of the marathon, the separated collection of the waste was applied only to the finish line. All the types of plastics were mixed in a single bin and collected to be managed according to the then-current plastic waste system. Along the route of the race, some volunteers collected the waste in the environment in an undifferentiated flow.

In this case, the visualisation model and the data would be the same for the marathon (distribution) and participants' (use) stages. Without the *#CORRIPULITO* stage, the box related to waste management and recycling would be different. In particular, only the plastic collected at the finish line (86.4 kg) would be sent to primary and secondary selection plants. This quantity would be sorted with the typical efficiency of the selection plants (Conte et al., 2018). Applying these values, the total quantity of plastics sent to recycling would be 52.7 kg. The single quantities sorted by polymer are shown in Table 10.

The remaining part of the flow collected at the finish line (33.7 kg) would be incinerated to recover 957.9 MJ of energy and would produce 4 kg of ash residue sent to landfill. Here, disposed waste would be added the quantity of undifferentiated plastics collected along the route of the race (130.7 kg), for a total quantity sent to landfill equal to 134.8 kg.

The values of the three KPIs in this situation would be:

1. $\eta_{C\ previous\ editions}(\%) = \left(\frac{W_{collected\ plastics}}{W_{distributed\ plastics}}\right) \cdot 100 = \left(\frac{86.4\ kg}{217.1\ kg}\right) \cdot\ 100 =$ 39.8%.
2. $RR_{previous\ editions}(\%) = \left(\frac{W_{recycled\ plastics}}{W_{distributed\ plastics}}\right) \cdot 100 = \left(\frac{52.7\ kg}{217.1\ kg}\right) \cdot\ 100 =$ 24.3%.
3. $LR_{previouseditions}(\%) = \left(\frac{W_{landfilledwaste}}{W_{distributedplastics}}\right) \cdot 100 = \left(\frac{134.8kg}{217.1kg}\right) \cdot 100 =$ 62.1%.

The entire visualisation tool set for the *#CORRIPULITO* initiative and its comparison to the typical situation of previous editions was provided in Fig. 12. The heights of the stages and their relative flows are proportional to the quantities of plastics determined in previous sections. To complete the visualisation throughout the entire life cycle of the plastics, data from the involved plastic manufacturer was collected to mainly identify and visually represent the plastic scraps (their average rate is 39%) and their recovery rate in the same process (100% – all the scraps are immediately reprocessed to manufacture other products). These values are the same in the two scenarios and provide indications of the effective quantity of virgin plastics required for the marathon. According to the general framework of the tool (Bianchini et al., 2019), the x-axis represents the product life cycle (time). In this specific case, the initiative #CORRIPULITO does not work with the extension of the life cycle, but it does with the increase in collection, sorting and recycling rates. Consequently, the effects of the initiative are relevant to the entire life cycle.

3.7. Economic sustainability

The economic evaluation was set for PET, since in the current market this is the polymer with greater recycling potential both in technical and economic terms (Eriksen et al., 2019; Franz et al., 2004). By inserting the numeric values of the *#CORRIPULITO* initiative in the condition of cost-effectiveness (Rel. 17), considering an industrial scale, the relation is:

$$p_{PET\ v} > \frac{0.037\ tonne \cdot 520.69\frac{\text{€}}{tonne} + 0.0384\ tonne \cdot \left(36.1\frac{\text{€}}{tonne} + 187.4\frac{\text{€}}{tonne}\right)}{0.0277\ tonne} = \text{€}1003.5 \Big/ tonne$$

This means that if the price of virgin PET is greater than €1003.5/tonne, the initiative is sustainable.

3.8. Social sustainability

Finally, from the questionnaire for the participants, the other two KPIs were evaluated. From questions *S1* and *S2*, a technical-environmental indicator about the reverse logistics was derived. This KPI is qualitative and was assessed using a Likert-type scale with three levels (Table 11), where 1 represents the lower level and 3 the upper level of performance. Due to the participants' answers,

Table 11
Likert scale elaborated to evaluate participants' answers to questions S1 and S2.

Reverse logistics structure	Level
The #CORRIPULITO project has provided the appropriate place/assets to separate plastic waste and to enable selective collection, and has increased participants' awareness of the proper materials and as well as a volunteer team. This was perceived as a positive aspect for most of runners and walkers (score: 9–10; from 70% to 100%).	3
The #CORRIPULITO project has provided the appropriate locations/assets to separate waste and to enable selective collection. This was perceived as a positive aspect and most of the runners and walkers perceived the infrastructure as adequate (score: 5–8; from 36% to 70%).	2
The #CORRIPULITO project did not provide the appropriate locations/assets to separate the waste and to enable the selective collection of the waste generated at the event (score: 0–4; from 0% to 35%).	1

Table 12
Likert scale elaborated to evaluate the participants' answers to question S3.

Participants' perceptions about initiative	Level
Most participants of the #CORRIPULITO project perceive the initiative related to the circular economy as positive (score 9–10; from 70% to 100%).	3
Approximately half of all participants of the #CORRIPULITO project perceive the initiative related to the circular economy as positive (score 5–8; from 36% to 70%).	2
A minority of participants of the #CORRIPULITO project perceive the initiative related to the circular economy as positive (score 0–4; from 0% to 35%).	1

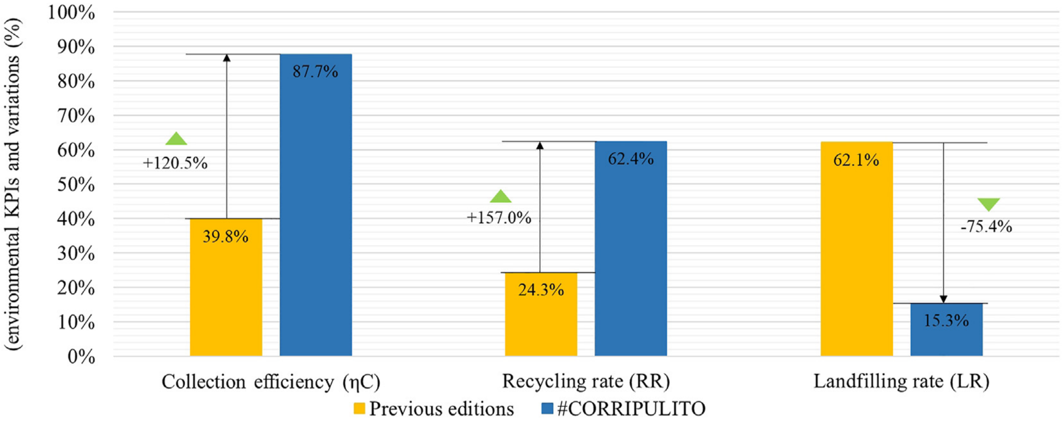


Fig. 13. Values of the selected KPIs to assess environmental sustainability and their variations in: (i) previous editions and (ii) the *#CORRIPULITO* initiative.

a score of 3 was obtained, which corresponds to the maximum.

Question *S3* provided information about the social impact of the initiative, similarly elaborated through a Likert scale (Table 12). Due to the participants' answers, a score of 3 was obtained, which corresponds to the maximum.

4. Discussion

The assessment of the *#CORRIPULITO* initiative demonstrates the sustainability of the proposed model to manage plastic waste at a sport event, maintaining all the benefits of this material but avoiding its negative impact on the environment. In particular, each of the three pillars of sustainability have been demonstrated.

From an environmental point of view, by comparing the initiative to the scenario that would have been present in previous editions of the event, we can see a significant improvement regarding the management and impact of plastic waste, as highlighted by the values of the selected KPIs: (i) collection efficiency (η_C) improved from 39.8% (previous editions) to 87.7% (*#CORRIPULITO*), an increase of 120.5%; (ii) the recycling rate (*RR*) increased by 157%, from a value of 24.3% (previous editions) to 62.4% (*#CORRIPULITO*); and, finally, the landfill rate (*LR*) decreased by 75.4%, dropping from 62.1% (previous editions) to 15.3% (*#CORRIPULITO*). Fig. 13shows the values of the three environmental KPIs and their variations in the two scenarios (*#CORRIPULITO* and previous editions of the marathon).

Nevertheless, the improvements obtained via the initiative required great efforts, mainly linked to the necessity to sort four types of plastics. One of the aspects with the greatest impacts that limits the quantity of plastics derived from recycling is the wide variety of polymers that end up as waste. A waste flow containing products made exclusively with one polymer can be quite easily recycled. Dahlbo et al. (2018), analysing 86,000–117,000 tonnes of post-consumer plastic packaging waste in Finland, demonstrating that the potential of plastic recycling through the separation of the greatest parts of mono-material plastic waste (consisting of PP and HDPE) from other plastic waste could be higher than the current recycling rate. In the current plastic waste management system, which gathers a mixed plastic flow in one bin, two separation stages are necessary to obtain a high-quality sorted flow of plastics. These stages are fundamental but are also the most critical ones since they require labour- and cost-intensive activities, with limited efficiencies (Ignatyev et al., 2014; Gala et al., 2020; Solis and Silveira, 2020). Gadaleta et al. (2020) assessed the techno-economic performance of a plastic waste sorting plant in southern Italy, which achieved a recovery index of greater than 95% with an annual cost of more than €3 million and a specific gain of €12.58/tonne. Pluskal et al. (2021) analysed several sorting lines for plastics, determining that only about 25% of the treated waste is sent to recycling. Several research papers have recognised waste sorting as the key process of waste recycling and have aimed to improve the sorting of plastic waste. With the aim of separating the most critical plastic waste, i.e. black plastics, due to their colour that does not allow their sorting with traditional separation technologies, Gruber et al. (2019) combined fluorescence imaging and machine learning, allowing the recognition of 14 plastics in 12 classes, while Rozenstein et al. (2017) used a midwave infrared spectroscopy to identify the polymer spectral features of coloured materials. Another approach to increase the sorting efficiency is based on the insertion of tracers into the materials, as described in Bezati et al. (2010), Arenas-Vivo et al. (2017) and Woidasky et al. (2020), who proposed to incorporate fluorescent markers in plastic containers.

As stated by Eriksen (2019), the heterogeneous features of plastics limits the potential for its recycling. A standardisation of the polymers and their properties for certain applications, above all eliminating the multilayer plastic products that cannot be cost-effectively recycled, would surely improve the management of plastic waste. This was the problem with the cups during the initiative. To simplify the separation of plastic waste for participants, plastics were classified for product typologies (bottles, plates, cups, cutlery) since it is difficult for consumers to sort plastics by polymer. However, a strict separation according to this criterion was not possible, since one type of cup (for coffee) was made from a different polymer compared to other cups. This discrepancy misled the participants, who were guided by volunteers.

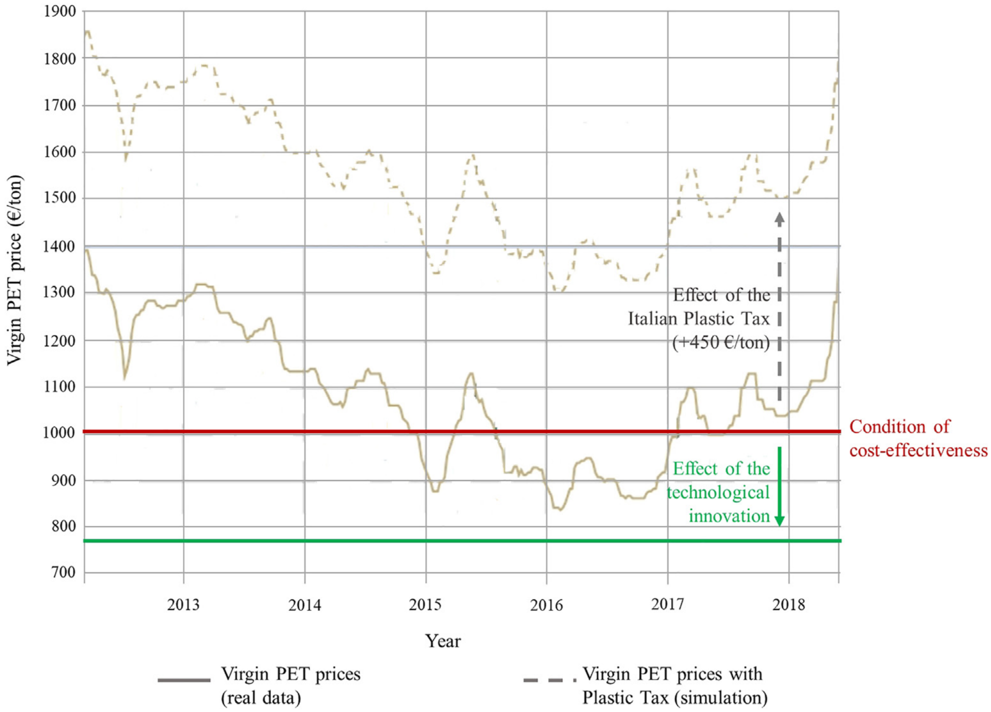


Fig. 14. Trend in virgin PET price over time: real data and simulation with the addition of the Italian Plastic Tax.

From this last topic, it is evident that the role of dedicated volunteers was fundamental. They ensured the assessment of the initiative, following the procedures to manage the collection points and to report data regarding the waste. However, their role was not to manage the waste and perform the collection and sorting of plastic waste. The *#CORRIPULITO* volunteers supervised the participants, inviting them and providing indications to properly manage their own waste. In fact, the participants were directly responsible for their own waste. The volunteers took the role of trainers for the public, activating good communication about the subject and the project. The importance of volunteers' role was also recognised by participants, as demonstrated by their responses to the questionnaire. The direct involvement of the participants, who were not left alone but were supported by volunteers, was key to the success of the initiative: it had a direct impact on collection efficiency, which increased, and the knowledge acquired about plastics and waste management ensured a more aware public, who had positive perceptions about the project. It demonstrates the social sustainability of the initiative. According to Donmez-Turan and Kiliclar (2021), creating a sustainable lifestyle requires making society aware of environmental protection and encouraging individuals to adopt environmental behaviours and practices. As stated by Amrutha and Geetha (2020), studies concerning social sustainability as an outcome of green human resource management practices are hard to find in the literature, and those that do exist are mainly focused on company employees. For example, Singh et al. (2019) found that environmental training should be a continuous process to support the competitiveness and environmental performance of companies; Jerónimo et al. (2020), recognising the importance of employee perception in order to increase company sustainability, investigated the best green practices (e.g. hiring, training, compensation) according to age and gender.

From an economic point of view, the condition of cost-effectiveness was determined. Briassoulis et al. (2020) proposed a list of indicators to assess the economic viability of the mechanical recycling of post-consumer waste, and particularly bio-based plastics: some criteria to evaluate include the availability of collected and sorted materials; the availability of mechanical recycling facilities; the quality of recyclates; the market for recycled materials; and financial feasibility. In this application, the cost-effectiveness depends on the price of virgin plastic material, in the evaluated case of virgin PET, which is characterised by a high volatility, as demonstrated in Fig. 14 (in 2019 the average virgin PET prize was €850/tonne) (Murray, 2018). Comparing the value that determines the cost-effective condition to the price trend of virgin PET over time (about €1000/tonne with data in Table 9), it can be noted that the initiative is economically sustainable for the greatest part of time. However, there are some periods in which the virgin PET price is lower than the average value, in which case an initiative like *#CORRIPULITO* would be not economically sustainable. Legislative strategies that aim to discourage the use of plastics, such as the Italian Plastic Tax, which adds a fee of €0.45 to every 1 kg of virgin plastic material, incentivises initiatives such as *#CORRIPULITO*. The effect of the Italian Plastic Tax is to increase the virgin PET price trend, extending the period during which the initiative is economically sustainable. One of the most promising approaches to obtain the same effect (an increase in the period in which the initiative is economically sustainable) is to decrease the value of the cost-effective condition. To do this, it is necessary to change the value of the parameters on the right side of Equation (17), increasing the efficiency of collection, sorting and recycling, or reducing the relative costs. The technological innovation in sorting and recycling plants has exactly this effect. For example, in considering the specific recycling plant of the involved partner, its current technological level allows an average process cost of €350/tonne ($C_{recycling}$), lower than the data from literature considered for the analysis. Using the data by partner, the cost-effective condition of the virgin PET price becomes €776/tonne, making *#CORRIPULITO* always sustainable from an economic point of view, too. Consequently, one of the most promising approaches to reducing the negative effect of plastics could be to incentivise the standardisation of plastics, the definition of simplified plastic waste

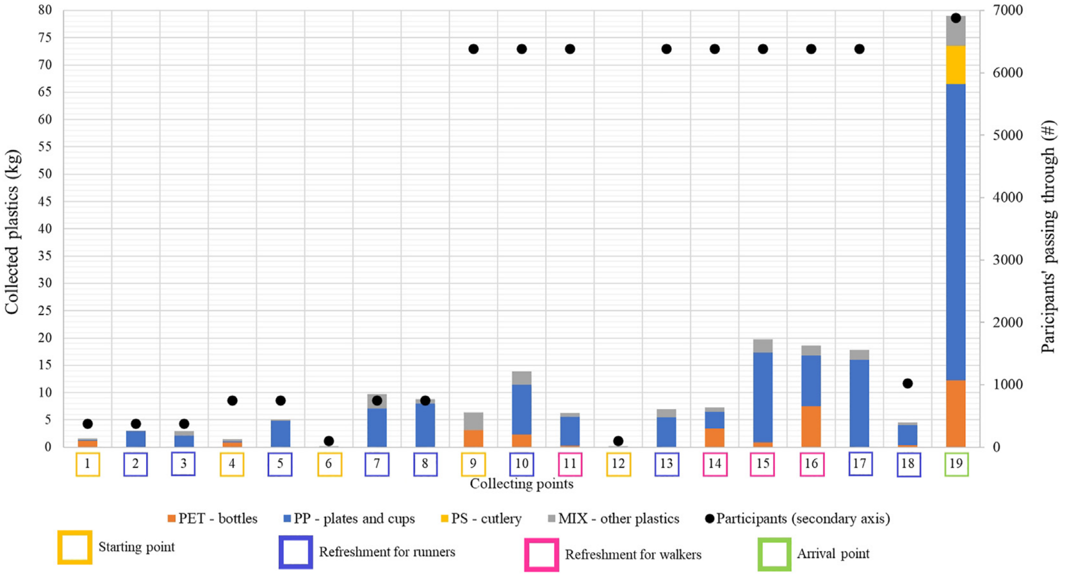


Fig. 15. Distribution of plastic waste (sorted by polymer) and the number of participants along the route of the race at different collecting points, distinguished by colour. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

management procedures and the technological innovation of sorting and recycling plants. Among several typologies of barriers to plastic circularity (legislative, market and socio-cultural barriers), Paletta et al. (2019) identified a list of technological barriers associated with plastic recyclers, such as a lack of innovation, low efficiency of the sorting system, the challenge of recycling regarding material contamination, and so on. Similarly, Hahladakis and Iacovidou (2019) analysed the main challenges and trade-offs of plastic waste mechanical recycling, considering contamination, sorting ability, degradation at reprocessing, substitutability, feasibility and so on. Investing in improving these aspects could lead to lower costs and/or higher revenues. This approach allows the spreading of innovation in the industrial context as opposed to penalisation through tax, which aims to eliminate the impact of plastic without providing an alternative, and taking the risk to shift to materials that only seem more sustainable than plastics. This approach is perfectly in line with the European Green Deal, which considers research and innovation key enablers in the transition to a more sustainable future for humans and a healthy planet.

The absolute novelty of the initiative is mainly related to the quantitative approach used to assess the flows of plastics and the sustainability of the proposed model. It consists of a detailed and precise methodology to obtain and collect a range of information, which can be useful for designing further editions of a marathon, other similar events in other locations and sustainable initiatives such as *#CORRIPULITO*.

One of the most useful pieces of information for marathon organisers is the distribution of plastic waste along the route of the race, as shown in Fig. 15.

From this distribution, marathon organisers can understand the consumption of plastic products at different types of refreshment point along the track and according to the number of participants passing through. It allows for a more precise determination of necessary resources (food, water, packaging, volunteers), ensuring the success of the event and avoiding excessive and unnecessary resources. The same results enable other initiatives such as *#CORRIPULITO* to optimise the design of the model (e.g. number and type of bins and rubbish bags, volunteers).

The main implications of this paper are three-fold. (i) Firstly, it provides a complete research method that includes all the phases necessary to effectively apply a circular initiative for waste management at sports events: the design, the practical implementation, and the assessment of a specific initiative related to plastic waste collection, sorting and recycling is provided for a marathon. Following the macro-structure of the consolidated PDCA method, which is typically applied to the manufacturing sector, the research method described here proposes specific sub-actions to set, for the first time, a circular waste management process for sports events, which requires the engagement of the relevant partners, the identification of the elements and the resources (also human resources) both for suitable waste management and participants' engagement, and finally the methodology and the tools to collect useful information for the assessment, based on which some improvement staps can be designed and then implemented for further editions of the same event. (ii) From a theory and research point of view, the main implications of the paper are related to the provision of specific data about plastic waste created during a marathon. No data was available on the distribution of plastic waste along the route of a marathon, in relation to participants and typology both of plastics and collection points. This data is useful to better understand the environmental impact of other similar sports events. Moreover, the visualisation tool proposed by Bianchini et al. (2019) is presented in detail in this paper for the first time. Consequently, it provides step-by-step instructions on how to replicate the use of the tool in other contexts. (iii) Finally, from a managerial point of view, the quantitative results regarding waste distribution and the method to assess the economic feasibility of the initiative will allow the replication of the initiative at other marathons or similar sports events, through its scalability according to the number of participants. The distribution of plastic waste can provide sports event organisations with relevant data to manage procurement (in quantity and typology), with the aim of reducing waste and simplifying its collection and sorting (and subsequently its recycling). Moreover, to measure the environmental sustainability of the initiative, indicators that measure a specific environmental parameter or impact have been selected. For practitioners, they are more straightforward to understand and monitor than compound indicators such as Ecological Footprint, which provides an indication of the global warming potential but is more difficult to use to improve the current situation.

5. Conclusions

This paper explains the methodology for the design, the implementation and the assessment of an initiative, based on CE concepts, to enable the sustainability of sports events through the improvement of plastic waste management at a small marathon event. It was quantitatively demonstrated that the shift to a waste management model based on a circular economy ensures and enables the sustainability of a sports event, covering the environmental, economic and social pillars, as summarised here:

- environmental benefits: + 120.5% in collection efficiency; +157.0% in recycling rate and −75.4% in landfill rate;
- economic conditions: with the technological level of the recycler, the initiative is efficient when the virgin PET price is greater than €776/tonne, which means at all times over the last six years and above all since the introduction of the Plastic Tax (+€450/tonne);
- social impact: the direct involvement of the participants (runners and walkers) and their positive perceptions of the initiative achieved the highest score of the two defined KPIs (3/3). When compared to KPIs of other sustainability pillars, the proposed social impacts are qualitative and are derived from a survey. This aspect can be further investigated as indicated in Paragraph 2.3.3 to quantitatively assess other impacts such as societal needs and values, necessary information and a proper method to acquire quantitative data must be defined.

Without a quantitative approach, which is a significant gap in the practical circular economy context, it is not possible to compare the benefits and weaknesses of two different waste management methods and verify the cost-effectiveness of reducing the environmental impacts.

This circular initiative made all the partners (including the participants of the sports event) responsible for their activities, and awareness of plastic waste must be increased since it consists of a resource. The standardisation of plastic applications, the training and the involvement of the consumer, and the incentive for a technological innovation allows the maximum recovery of the value of plastic waste, reducing the impact both at the beginning and the end of the life of plastic (extraction of raw material and disposal in landfill or, in the worst case, littering in land and sea). A legislative strategy is necessary to support this transition.

A further application of this approach (integration of partner, design of sustainable initiative, practical implementation and assessment), which aims to effectively implement a circular economy applied to plastic waste management, has already been proposed for another type of plastic product, namely trays for food packaging. The project is under development and aims to contribute significantly to the achievement of the targets set by European strategy for plastics, which established that, by 2030, 55% of plastics must be recycled (in 2017 this value was 41.9%). Another application of this approach, to quantify the sustainability through specific KPIs, is under development in the field of nutrients recovery (phosphorous) in diary sector through the European project Prosumer, financed by Climate KIC.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Augusto Bianchini: Conceptualization, Methodology, Supervision, Validation, Writing - review & editing. **Jessica Rossi:** Data curation, Writing - original draft, preparation, Visualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge the partners involved in the initiative described in the paper. These are Romagna Iniziative, for the communication of the project (press conference, communication on social media, volunteers' T-shirts) and in particular Siropack Italia s. r.l. (a member of Romagna Iniziative) and TAILOR Laboratory, which contributed significantly to the conception of the initiative and to the involvement of partners and the supply of the equipment necessary to implement the initiative (bins, communication panel, reverse logistics costs, personnel). We would like to thank Maratona Alzheimer for being our case study and providing the data and information. All three partners were involved in the recruitment of the dedicated volunteers. Other partners provided their resources to conduct activities for the initiative and to provide data: Ilpa Group (plastic manufacturer and recycler); Hera Group (multi-utility); and Corepla (Italian Consortium for plastic waste management). Finally, the authors acknowledge the EIT Climate-KIC, which funded the project Prosumer (EIT_2.2.2_200103_P125_1A) providing the opportunity to consolidate and disseminate the proposed methodology.

References

Abbas, M., Gao, Y., Shah, S., 2018. CSR and customer outcomes: the mediating role of customer engagement. Sustainability 10, 4243. https://doi.org/10.3390/su10114243.

Agostinho, F., Richard Silva, T., Almeida, C.M.V.B., Liu, G., Giannetti, B.F., 2019. Sustainability assessment procedure for operations and production processes (SUAPRO). Sci. Total Environ. 685, 1006–1018. https://doi.org/10.1016/j.scitotenv.2019.06.261.

Amrutha, V.N., Geetha, S.N., 2020. A systematic review on green human resource management: implications for social sustainability. J. Clean. Prod. 247, 119131. https://doi.org/10.1016/j.jclepro.2019.119131.

Arenas-Vivo, A., Beltràn, F.R., Alcàzar, V., de la Orden, M.U., Urreaga, J.M., 2017. Fluorescence labeling of high density polyethylene for identification and separation of selected containers in plastics waste streams. Comparison of thermal and photochemical stability of different fluorescent tracers. Mater. Today Commun 12, 125–132. https://doi.org/10.1016/j.mtcomm.2017.07.008.

Atchariyasopon, K., 2017. Sustainable Solid Waste Management in Sports Events: A Case Study of Football Matches in Thailand. JPSS 25, 59–81. https://doi.org/10.14456/jpss.2017.6.

Azienda Servizi Ambientali (ASA). Elenco prezzi. Available online: http://www.asambiente.it/wordpress/wp-content/uploads/elenco_prezzi.pdf. accessed on 6th April 2020).

Barbieri, R., Santos, D.F.L., 2020. Sustainable business models and eco-innovation: a life cycle assessment. J. Clean. Prod. 266, 121954. https://doi.org/10.1016/j.jclepro.2020.121954.

Barra, R., Leonard, S.A., Whaley, C., Bierbaum, R., 2018. Plastics and the Circular Economy. STAP - Scientific and Technical Advisory Panel to the Global Environment Facility, Washington, DC.

Bezati, F., Froelich, D., Massardier, V., Maris, E., 2010. Addition of tracers into the polypropylene in view of automatic sorting of plastic wastes using X-ray fluorescence spectrometry. Waste Manag. 30, 591–596. https://doi.org/10.1016/j.wasman.2009.11.011.

Bianchini, A., Pellegrini, M., Rossi, J., Saccani, C., 2018. A new productive model of circular economy enhanced by digital transformation in the Fourth Industrial Revolution - an integrated framework and real case studies. In: Proceedings of XXIII Summer School “Francesco Turco”, Palermo, Italy, September 12-14, 2018.

Bianchini, A., Rossi, J., Pellegrini, M., 2019. Overcoming the main barriers of circular economy implementation through a new visualization tool for circular business models. Sustain. Times 11, 6614. https://doi.org/10.3390/su11236614.

Bianchini, A., Guarnieri, P., Rossi, J., 2020. Assessing social sustainability in A circular model: application in an Italian luxury footwear industry. In: Proceedings of the

5th Symposium on Urban Mining and Circular Economy - SUM2020, Bologna, Italy, 18-20 May 2020 stage of publication: accepted.

Briassoulis, D., Pikasi, A., Hiskakis, M., 2020. Recirculation potential of post-consumer/industrial bio-based plastics through mechanical recycling - techno-economic sustainability criteria and indicators. Polym. Degrad. Stabil. 109217. https://doi.org/10.1016/j.polymdegradstab.2020.109217.

Calleja, D., 2019. Why the "New Plastics Economy" must be a circular economy. Field Actions Science Reports (Online), Institut Veolia - Facts Reports 19, 22–27, 2019.

Camacho, D.P., Dos Santos, M.A., Duclos, D., 2018. Residents' perceptions of the negative impacts of the Copa América de Futbol in Chile: pre- and post- event comparison. J. Phys. Educ. Sport 18 (3), 1290–1297.

Chen, K.-C., Gursoy, D., Lau, K.L.K., 2018. Longitudinal impacts of a recurring sport event on local residents with different level of event involvement. Tour. Manag. Perspect. 28, 228–238. https://doi.org/10.1016/j.tmp.2018.09.005.

Chen, T.-L., Kim, H., Pan, S.-Y., Tseng, P.-C., Lin, Y.-P., Chiang, P.-C., 2020. Implementation of green chemistry principles in circular economy system towards sustainable development goals: challenges and perspectives. Sci. Total Environ. 716, 136998. https://doi.org/10.1016/j.scitotenv.2020.136998.

Chernushenko, D., 1994. Greening Our Games, Delphi Ed. Centurion Publishing & Marketing, Ottawa, Ontario, Canada.

Chuah, S.H.-W., El-Manstrly, D., Tseng, M.-L., Ramayah, T., 2020. Sustaining customer engagement behavior through corporate social responsibility: the roles of environmental concern and green trust. J. Clean. Prod. 262, 121348. https://doi.org/10.1016/j.jclepro.2020.121348.

Coalter, F., Taylor, J., 2008. Large Scale Sports Events: Event Impact Framework. Report to UK Sport, 1rs ed. University of Stirling, Stirling, Scotland.

Collins, A., Jones, C., Munday, M., 2009. Assessing the environmental impacts of mega sporting events: two options? Tourism Manag. 30, 828–837. https://doi.org/10.1016/j.tourman.2008.12.006.

Conte, C., Navarotto, P., Grosso, M., 2018. Analisi sperimentale di un impianto di selezione avanzata dei rifiuti plastici da raccolta differenziata (Experimental Analysis of an Advanced Sorting Plant for Plastic Packaging Waste). Ing. Ambiente 5 (3), 199–212. https://doi.org/10.32024/ida.v5i3.p04.

COREPLA, 2018. Relazione sulla gestione 2018 (report about management 2018). Available online: http://www.corepla.it/documenti/c3cc963b-c446-46c3-809b-e17e487f8e2d/RELAZIONE+SULLA+GESTIONE+2018.pdf (accessed on 6th April 2020)..

Council for Responsible Sport. Responsible sport certification. Available online: https://static1.squarespace.com/static/5ad515a3b27e3996f0e0fa73/t/5afcb6a3562fa74f96bb1d60/1526511268172/4.2_Responsible_Sport_Certification_Standards.pdf (accessed on 6th April 2020).

Dahlbo, H., Poliakova, V., Mylläri, V., Sahimaa, O., Anderson, R., 2018. Recycling potential of post-consumer plastic packaging waste in Finland. Waste Manag 71, 52–61. https://doi.org/10.1016/j.wasman.2017.10.033.

de Subijana, C.L., Moro, M.B., Lozano, P.R., 2014. Perception of sports events held in A permanent sports facility: the case of the madrid sports palace. Kinesiology 46 (2), 266–276.

Dijkstra, H., van Beukering, P., Brouwer, R., 2020. Business models and sustainable plastic management: a systematic review of the literature. J. Clean. Prod. 258, 120967. https://doi.org/10.1016/j.jclepro.2020.120967.

Dolf, M., Teehan, P., 2015. Reducing the carbon footprint of spectator and team travel at the University of British Columbia's varsity sports events. Sport Manag. Rev. 18, 244–255. https://doi.org/10.1016/j.smr.2014.06.003.

Donmez-Turan, A., Kiliclar, I.E., 2021. The analysis of pro-environmental behaviour based on ecological worldviews, environmental training/knowledge and goal frames. J. Clean. Prod. 279, 123518. https://doi.org/10.1016/j.jclepro.2020.123518.

Ellen MacArthur Foundation, 2016. The New Plastics Economy. Ellen MacArthur Foundation, pp. 1–120.

Erichsen, H.L., Hauschild, M.Z., 2000. Technical Data for Waste Incineration - Background for Modelling of Product-specific Emissions in a Life Cycle Assessment Context. Institut for Produktion og Ledelse, DTU, Kongens Lyngby, Denmark.

Eriksen, M.K., Christiansen, J.D., Daugaard, A.E., Astrup, T.F., 2019. Closing the loop for PET, PE and PP waste from households: influence of material properties and product design for plastic recycling. Waste Manag. 96, 75–85.

European Commission, 2018. A European strategy for plastics in a circular economy. Available online: https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf. accessed on 6th April 2020.

Franz, R., Bayer, F., Welle, F., 2004. European Commission; Directorate General for Research; Unit E2 - Food Quality; European Commission; Directorate General for Research; FAIR - Fisheries and Agriculture Guidance and Criteria for Safe Recycling of Post Consumer Polyethylene Terephthalate (PET) into New Food Packaging Applications. Directorate-General for Research, FAIR - Fisheries and Agriculture, Brussels.

Gadaleta, G., De Gisi, S., Binetti, S.M.C., Notarnicola, M., 2020. Outlining a comprehensive techno-economic approach to evaluate the performance of an advanced sorting plant for plastic waste recovery. Process Saf. Environ. Protect. 143, 248–261. https://doi.org/10.1016/j.psep.2020.07.008.

Gala, A., Guerrero, M., Serra, J.M., 2020. Characterization of post-consumer plastic film waste from mixed MSW in Spain: A key point for the successful implementation of sustainable plastic waste management strategies. Waste Manag 111, 22–33. https://doi.org/10.1016/j.wasman.2020.05.019.

Garza-Reyes, J.A., Romero, J.T., Govindan, K., Cherrafi, A., Ramanathan, U., 2018. A PDCA-based approach to Environmental Value Stream Mapping (E-VSM). J. Clean. Prod 180, 335–348. https://doi.org/10.1016/j.jclepro.2018.01.121.

Gibson, H.J., Kaplanidou, K., Kang, S.J., 2012. Small-scale event sport tourism: a case study in sustainable tourism. Sport Manag. Rev. 15, 160–170. https://doi.org/10.1016/j.smr.2011.08.013.

Gligor, D., Bozkurt, S., Russo, I., 2019. Achieving customer engagement with social media: a qualitative comparative analysis approach. J. Bus. Res. 101, 59–69. https://doi.org/10.1016/j.jbusres.2019.04.006.

Gong, Y., Putnam, E., You, W., Zhao, C., 2020. Investigation into circular economy of plastics: the case of the UK fast moving consumer goods industry. J. Clean. Prod. 244, 118941. https://doi.org/10.1016/j.jclepro.2019.118941.

Gruber, F., Grählert, W., Wollmann, P., Kaskel, S., 2019. Classification of Black Plastics Waste Using Fluorescence Imaging and Machine Learning, p. 17.

Guarnieri, P., Pagani, R.N., Santos, R.R., Campos, E.A.R., Paula, I.C., Cerqueira-Streit, J.A., 2020. A survey of indicators to measure the social dimension of Triple Bottom Line. In: Proceedings of International Conference of Resources Sustainability – ICRS 2020, Dublin, Ireland, June 30-July 2, 2020.

Hahladakis, J.N., Iacovidou, E., 2019. An overview of the challenges and trade-offs in closing the loop of post-consumer plastic waste (PCPW): Focus on recycling. J. Hazard. Mater. 380, 120887. https://doi.org/10.1016/j.jhazmat.2019.120887.

Ignatyev, I.A., Thielemans, W., Vander Beke, B., 2014. Recycling of polymers: a review. ChemSusChem 7, 1579–1593.

ISPRA, 2018 data. Catasto Rifiuti Sezione Nazionale. Costi di gestione nazionali e per macroarea. Costi di gestione regioni area: Italia. Available online. https://www.catasto-rifiuti.isprambiente.it/index.php?pg=costiregione. accessed on 6th April 2020.

Jerónimo, H.M., Henriques, P.L., de Lacerda, T.C., da Silva, F.P., Vieira, P.R., 2020. Going green and sustainable_ The influence of green HR practices on the organizational rationale for sustainability. J. Bus. Res. 112, 413–421. https://doi.org/10.1016/j.jbusres.2019.11.036.

Kim, E., Fredline, L., Cuskelly, G., 2018. Heterogeneity of sport event volunteer motivations: A segmentation approach. Tour. Manag 68, 375–386. https://doi.org/10.1016/j.tourman.2018.04.004.

Klenk, F., Gleich, K., Meister, F., Häfner, B., Lanza, G., 2020. Approach for developing implementation strategies for circular economy in global production networks. Procedia CIRP 90, 127–132. https://doi.org/10.1016/j.procir.2020.01.052.

Konietzko, J., Bocken, N., Jan Hultink, E., 2020. Circular ecosystem innovation: An initial set of principles. J. Clean. Prod. 253, 11942. https://doi.org/10.1016/j.jclepro.2019.119942.

Kristiansen, E., Skirstad, B., Parent, M.M., Waddington, I., 2015. 'We can do it': community, resistance, social solidarity, and long-term volunteering at a sport event. Sport Manag. Rev. 18, 256–267. https://doi.org/10.1016/j.smr.2014.06.002.

Lee, Y., Kim, M., Koo, J., 2016. The impact of social interaction and team member exchange on sport event volunteer management. Sport Manag. Rev. 19, 550–562. https://doi.org/10.1016/j.smr.2016.04.005.

Li, B., Wang, F., Yin, H., Li, X., 2019. Mega events and urban air quality improvement: a temporary show? J. Clean. Prod. 217, 116–126. https://doi.org/10.1016/j.jclepro.2019.01.116.

Mallen, C., Stevens, J., Adams, L., McRoberts, S., 2010. The assessment of the environmental performance of an international multi-sport event. Eur. Sport Manag. Q. 10, 97–122. https://doi.org/10.1080/16184740903460488.

Manni, M., Coccia, V., Nicolini, A., Marseglia, G., Petrozzi, A., 2018. Towards zero energy stadiums: the case study of the dacia arena in udine, Italy. Energies 11, 2396. https://doi.org/10.3390/en11092396.

Martinho, G., Gomes, A., Ramos, M., Santos, P., Gonçalves, G., Fonseca, M., Pires, A., 2018. Solid waste prevention and management at green festivals: A case study of the Andanças Festival, Portugal. Waste Manag 71, 10–18. https://doi.org/10.1016/j.wasman.2017.10.020.

Mastellone, M.L., 2020. Technical description and performance evaluation of different packaging plastic waste management's systems in a circular economy perspective. Sci. Total Environ. 718, 137233. https://doi.org/10.1016/j.scitotenv.2020.137233.

Mendoza, J.M.F., Gallego-Schmid, A., Azapagic, A., 2019. Building a business case for implementation of a circular economy in higher education institutions. J. Clean. Prod. 220, 553–567. https://doi.org/10.1016/j.jclepro.2019.02.045.

Meza Talavera, A., Al-Ghamdi, S., Koç, M., 2019. Sustainability in mega-events: beyond Qatar 2022. Sustain. Times 11, 6407. https://doi.org/10.3390/su11226407.

Moktadir, A., Ahmadi, H.B., Sultana, R., Zohra, F.-T., Liou, J.J.H., Rezaei, J., 2020. Circular economy practices in the leather industry: A practical step towards sustainable development. J. Clean. Prod. 251, 119737. https://doi.org/10.1016/j.jclepro.2019.119737.

Murray, C., 2018. Europe PET Price Soars 30% in First Five Months of 2018 on Unprecedented Tightness. ICIS. https://www.icis.com/explore/resources/news/2018/06/07/10228791/europe-pet-price-soars-30-in-first-five-months-of-2018-on-unprecedented-tightness/. accessed on 6th April 2020.

Nsafon, B.E.K., Butu, H.M., Owolabi, A.B., Roh, J.W., Suh, D., Huh, J.-S., 2020. Integrating multi-criteria analysis with PDCA cycle for sustainable energy planning in Africa: application to hybrid mini-grid system in Cameroon. Sustain. Energy Technol. Assess. 37, 100628. https://doi.org/10.1016/j.seta.2020.100628.

Paletta, A., Leal Filho, W., Balogun, A.-L., Foschi, E., Bonoli, A., 2019. Barriers and challenges to plastics valorisation in the context of a circular economy: case studies from Italy. J. Clean. Prod. 241, 118149. https://doi.org/10.1016/j.jclepro.2019.118149.

Pereira, R.P.T., Filimonau, V., Riberio, G.M., 2019. Score a goal for climate: Assessing the carbon footprint of travel patterns of the English Premier League clubs. J. Clean. Prod 227, 167–177. https://doi.org/10.1016/j.jclepro.2019.04.138.

Pereira, R.P.T., Camara, M.V.O., Ribeiro, G.M., Filimonau, V., 2017. Applying the facility location problem model for selection of more climate benign mega sporting event hosts: a case of the FIFA World Cups. J. Clean. Prod. 159, 147–157. https://doi.org/10.1016/j.jclepro.2017.05.053.

Perić, M., Slavić, N., 2019. Event sport tourism business models: the case of trail running. Sport Bus. Manag. Int. J. 9, 164–184. https://doi.org/10.1108/SBM-05-2018-0039.

Perić, M., Vitezić, V., Badurina, J.Đ., 2019. Business models for active outdoor sport event tourism experiences. Tour. Manag. Perspect. 32, 100561. https://doi.org/10.1016/j.tmp.2019.100561.

Petriglieri, S., 2014. Esperienza di COREPLA nel trattamento delle plastiche, con speciale riguardo al potenziale utilizzo di PLASMIX additivo per la confezione di CSS. Available online. http://ecocarbon.it/wp-content/uploads/2014/10/04-PETRIGLIERI-Corepla-e-il-CSS.pdf. accessed on 6th April 2020.

Pieroni, M.P.P., McAloone, T.C., Pigosso, D.C.A., 2020. From theory to practice: systematising and testing business model archetypes for circular economy. Resour. Conserv. Recycl. 162, 105029. https://doi.org/10.1016/j.resconrec.2020.105029.

Plastics Europe. Plastics - The Facts 2019 - An Analysis of European plastics production, demand and waste data. PlasticsEurope. Available online https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_14102019.pdf (accessed on 2th December 2020).

Plevnik, M., Obid, A., 2015. In: Plevnik, M., Retar, I., Pisot, R., Obid, A. (Eds.), Sustainable Development of Sports Tourism. Annales University Press.

Pluskal, J., Somplak, R., Nevrlý, V., Smejkalova, V., Pavlas, M., 2021. Strategic decisions leading to sustainable waste management: Separation, sorting and recycling possibilities. J. Clean. Prod. 278, 123359. https://doi.org/10.1016/j.jclepro.2020.123359.

Prashar, A., 2017. Adopting PDCA (Plan-Do-Check-Act) cycle for energy optimization in energy-intensive SMEs. J. Clean. Prod. 17.

Rafiee, A., 2018. The impact of various festivals and events on recycling potential of municipal solid waste in Tehran, Iran. J. Clean. Prod. 10.

Replay Plastics. Plastics recycling business plan. Available online: https://www.bplans.com/plastics_recycling_business_plan/executive_summary_fc.php (accessed on 6th April 2020)..

Rossi, J., Bianchini, A., Guarnieri, P., 2020. Circular economy model enhanced by intelligent assets from industry 4.0: the proposition of an innovative tool to analyze case studies. Sustain. Times 12 (17), 7147. https://doi.org/10.3390/su12177147.

Rozenstein, O., Puckrin, E., Adamowski, J., 2017. Development of a new approach based on midwave infrared spectroscopy for post-consumer black plastic waste sorting in the recycling industry. Waste Manag. 68, 38–44. https://doi.org/10.1016/j.wasman.2017.07.023.

Sánchez Levoso, A., Gasol, C.M., Martínez-Blanco, J., Durany, X.G., Lehmann, M., Gaya, R.F., 2020. Methodological framework for the implementation of circular economy in urban systems. J. Clean. Prod. 248, 119227. https://doi.org/10.1016/j.jclepro.2019.119227.

Scrucca, F., Severi, C., Galvan, N., Brunori, A., 2016. A new method to assess the sustainability performance of events: application to the 2014 World Orienteering Championship. Environ. Impact Assess. Rev. 56, 1–11. https://doi.org/10.1016/j.eiar.2015.08.002.

Singh, S.K., Chen, J., Del Giudice, M., El-Kassar, A.-N., 2019. Environmental ethics, environmental performance, and competitive advantage: Role of environmental training. Technol. Forecast. Soc. Change 146, 203–211. https://doi.org/10.1016/j.techfore.2019.05.032.

Solis, M., Silveira, S., 2020. Technologies for chemical recycling of household plastics – a technical review and TRL assessment. Waste Manag. 105, 128–138. https://doi.org/10.1016/j.wasman.2020.01.038.

UISP Emilia-Romagna. Manuale eventi sportivi sostenibili (Handbook sustainable sport events). Available online: http://www.uisp.it/vela2/files/principale/uisp_manuale_eventi_sportivi_sostenibili.pdf (accessed on 6th April 2020).

Woidasky, J., Sander, I., Schau, A., Moesslein, J., Wendler, P., Wacker, D., Gao, G., Kirchenbauer, D., Kumar, V., Busko, D., Howard, I.A., Richards, B.S., Turshatov, A., Wiethoff, S., Lang-Koetz, C., 2020. Inorganic fluorescent marker materials for identification of post-consumer plastic packaging. Resour. Conserv. Recycl. 161, 104976. https://doi.org/10.1016/j.resconrec.2020.104976.

Yadav, G., Mangla, S.K., Bhattacharya, A., Luthra, S., 2020. Exploring indicators of circular economy adoption framework through a hybrid decision support approach. J. Clean. Prod. 277, 124186. https://doi.org/10.1016/j.jclepro.2020.124186.

Yao, Q., Schwarz, E.C., 2018. Impacts and implications of an annual major sport event: a host community perspective. J. Destin. Mark. Manag. 8, 161–169. https://doi.org/10.1016/j.jdmm.2017.02.007.

Yeh, C.-C., Huang, C.-H., 2015. An innovative trend of sport event in environmental perspective. In: Leng, H.K., Hsu, N.Y. (Eds.), Emerging Trends and Innovation in Sports Marketing and Management in Asia, Advances in Marketing, Customer Relationship Management, and E-Services; IGI Global.