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Evaluating the Sustainability of a Sport Event through LCSA-Based framework

A Comprehensive Analysis of the Granfondo La Fausto Coppi's Triple Bottom Line

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Abstract

Sustainability, defined as the intersection of environmental, economic, and social aspects has been the main theme in recent years. In this context, the sport industry plays a proactive role, the mass resonance of sport events makes them powerful tools to promote more responsible behavior and inspire sustainable practices. Triple Bottom Line (TBL) approach provides a directional framework to assess sustainability performance across its three dimensions. However, existing studies on events often lack methodological homogeneity focusing on single dimensions or adopting tailor-made methods that cannot be easily applied to small-medium scale events. This analysis applies a Life Cycle Sustainability Assessment (LCSA) framework to the 2024 edition of the Granfondo La Fausto Coppi, a medium scale cycling event held in Cuneo, Italy, which gathered 2,300 participants and an estimated 7,138 total attendances over the three-day event. The methodological approach follows a common goal and scope definition across all three dimensions, with carefully motivated assumptions in order to adapt standardized methods such as LCSA to the context of the event. The objective is twofold: on one hand, to evaluate the sustainability performance of the event, identifying areas of improvement and providing insights for the event organizers and stakeholders; on the other hand, to propose an integrated and replicable methodology for the comprehensive analysis of small and medium-sized events, in line with ISO standards and the LCSA framework. For the environmental dimension, the event generated 54.14 tonnes of CO_2e within the defined system boundaries, corresponding to 7.58 kg CO_2e per attendee. The study reveals that the adoption of sustainable practices - some already implemented and others modeled in the best-case scenario - would lower emissions by nearly 20% compared to a conservative scenario. Economically, the event generated an estimated overall impact of €1.83 million on the local community, calculated through direct expenditures and multipliers, with participants and visitors spending resulting as the main contributor. Socially, the event showed strong international appeal, with participants from 36 countries, while maintaining a significant local relevance, reflected by a 53% return rate across previous editions and high levels of participant satisfaction. By integrating these three dimensions, the study demonstrates the potential of the LCSA approach to provide a holistic and comparable measure of event sustainability, supporting organizational decision-making and fostering the development of sustainable events.

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Chapter 1

Introduction

1.1 Sustainability

Sustainability has emerged as one of the dominant aspects of this time. What was once a rather marginal concept only a few decades ago has now entered everyday language and practice, shaping political agendas, corporate strategies, and even personal choices. Today it is almost impossible to discuss major global issues - whether climate change, resource use, or social inequality - without invoking sustainability in some form. In broad terms, sustainability entails using and managing resources in a manner that can be maintained without depleting them, ensuring that human needs can be met not just in the present, but also in the future. Sustainable development builds on this foundation as the actionable pathway towards achieving sustainability. The term was formally introduced by the World Commission on Environment and Development in 1987 and is widely defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs[57]"*. The growing awareness of the imbalance between human activities and natural systems has progressively reinforced the importance of sustainable development as a guiding principle for policy, research, and practice. Over the past decades, numerous methods and indicators have been developed to monitor and steer progress toward sustainability.

In this context, sustainable development has become a central concept in both scientific and policy debates, strongly supported by the *Sustainable Development Goals* (SDGs) introduced by the United Nations in 2015 as part of the 2030 Agenda. The 17 Goals, reported in Figure 1.1, represent a global call to action to end poverty, protect the planet, and ensure that by 2030 all people can enjoy peace and prosperity, moving towards a better and a more sustainable future for all. SDGs aim to integrate economic growth, social well-being, and environmental concerns into a comprehensive roadmap for global development [50].

Figure 1.1: United Nations Sustainable Development Goals [50]

This thesis aligns with the SDG framework by addressing three Goals that are particularly relevant to the case study analyzed. The primary goal is SDG 11 - Sustainable Cities and Communities, as the analysis focuses on a local area and evaluates the social and economic impact of a sport event on the host community. In addition, two secondary SDGs are considered: SDG 8 - Decent Work and Economic Growth, since the event generates an economic stimulus for local businesses, and SDG 12 - Responsible Consumption and Production, which reflects the environmental assessment of the case study.

The SDGs, by definition, embody a multi-dimensional perspective, requiring the integration of environmental protection, social well-being, and economic development. However, one of the main challenges in their implementation lies in the difficulty of moving beyond fragmented or one-dimensional assessments. In this sense, Valdivia and Sonnemann, in their *Handbook on Life cycle Sustainablity Assessment (2024)* [51], describe the Life Cycle Sustainability Assessment (LCSA) as a particularly suitable methodology. Both the SDGs and LCSA share a holistic vision of the world, its populations, and the development process. While LCSA is not formally structured around the 17 individual goals, it rests on the same three pillars of sustainability - environmental, social, and economic - that are also central to the SDGs. Moreover, the long-term perspective promoted by the SDGs aligns closely with life cycle thinking, which seeks to capture impacts across time and throughout the entire chain of activities. This methodology, firstly introduced by Kloepffer in the *International Journal of Life Cycle Assessment (2008)* [32], integrates the three most established life cycle approaches - Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA) - thus offering a consistent framework for sustainability assessment, fully grounded in the Triple Bottom Line (TBL) approach.

1.1.1 Triple Bottom Line

Triple bottom line (TBL) is a sustainability-related construct that was coined by Elkington in the book *Cannibals with forks- Triple bottom line of 21st century business* published in 1997 [18]. TBL expresses the expansion of the environmental agenda in a way that integrates the economic and social lines. Driven by sustainability, it provides a framework for measuring the performance of businesses and the success of organizations using the economic, social, and environmental lines.

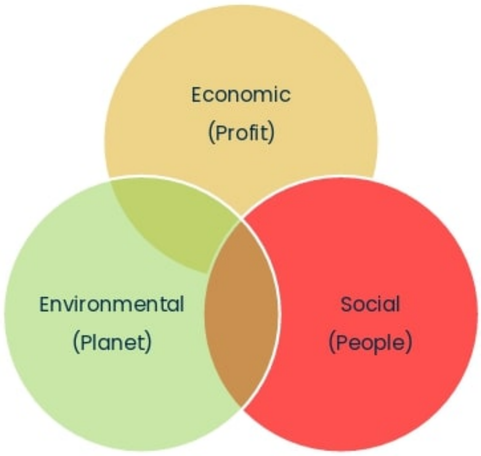

Figure 1.2: Triple Bottom Line

In his definition of Triple Bottom Line, Elkington used the terms Profit, People, and Planet as the three lines as shown in Figure 1.2. As described by the author, the economic line refers to the impact of the organization's business practices on the economic system: it focuses on the economic value provided by the organization to the surrounding system in a way that prospers it and promotes its capability to support future generations. The social line refers to conducting beneficial and fair business practices to the labor, human capital, and to the community [18]. These practices aim to create value for society and "give back" to the community, aligning closely with the principles of corporate social responsibility (CSR), which can be defined as a company's commitment to integrate social concerns into its operations and interactions with stakeholders.

Finally, the last element of the construct is the environmental line, which emphasizes the involvement in practices that do not compromise the environmental resources for future generations. This involves the efficient use of energy resources, reducing greenhouse gas emissions, and minimizing the ecological footprint.

The Triple Bottom Line (TBL) assessment is challenging due to the lack of a common unit and methodology across the economic, environmental, and social dimensions. While economic performance can be easily expressed in monetary terms, environmental and social aspects require context-specific indicators. The absence of a standardized method, however, can be seen as a point of strength: it allows the TBL approach to be adapted according to the goals, scope, and context of different organizations or projects, ensuring more relevant and meaningful sustainability assessments.

By focusing on the interdependence of environmental, economic, and social aspects, the TBL framework highlights the importance of an integrated evaluation approach. The Life Cycle Sustainability Assessment (LCSA) method can meet this need by consistently assessing all three pillars throughout the entire life cycle of a product, process, or organization, thus enabling a holistic understanding of sustainability performance, taking into account all three dimensions of sustainability.

According to Elkington's triple bottom line (TBL) framework, the three pillars of sustainability - economic, environmental, and social - are equally important and interdependent, generally illustrated as three intersecting circles in a Venn diagram as shown in Figure 1.2. This concept promotes a balanced approach that brings coherence into the construct in which sustainability is achieved at the intersection of the three dimensions.

In contrast, the concept of strong sustainability, as shown in Figure 1.3, adopts a hierarchical perspective, representing the three dimensions as nested circles, with the environment as the outer and most crucial layer, containing society, which then encompasses the economy. This structure reflects the idea that economic and social systems ultimately rely on the integrity of natural systems.

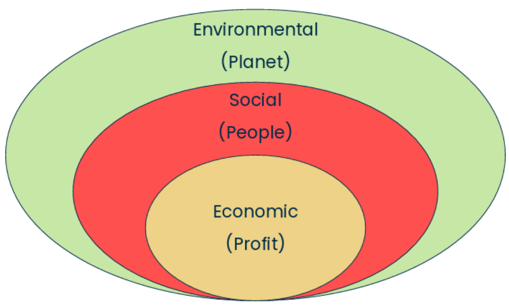

Figure 1.3: Visual representation of strong sustainability

Strong sustainability argues that the overall value of natural capital must remain undiminished for future generations, asserting that natural capital is non-substitutable by human or financial capital. This view treats sustainability as a multiplicative concept, where the degradation of any capital limits overall sustainability. In contrast, weak sustainability assumes that different forms of capital are substitutable and conceptualizes sustainability additively, allowing for trade-offs and compensation among environmental, social, and economic dimensions.

1.2 Sport and Sustainability

Sustainability has increasingly become a key focus in business, driven by new models of innovation, better risk management, growing awareness among consumers, and the widespread diffusion of sustainability reporting. Within this context, the sports industry represents a particularly effective tool: thanks to its global resonance, growing appeal, its capacity to attract wide audiences, and its role in shaping cultural traditions, sport is increasingly positioned not only as a driver of economic value but also as a tool for promoting sustainable practices and driving social change.

In Italy, the sport industry plays a significant role in the national economy. According to IRES , during the period between 2012 and 2019, the industry generated €24.5 billion of added value, while sports tourism alone accounted for €7.6 billion in 2019 - equivalent to 0.42% of the national GDP [14]. The Piedmont region, specifically, is home to a long-standing sporting tradition, from the foundation of the Italian Alpine Club in 1865 and the first ski club in 1906, to international competitions such as the Winter Olympic Games in 2006. This tradition was officially recognized with the designation of Piedmont as European Region of Sport for the 2022 year, hosting major events like *Giro d'Italia, Nitto ATP Finals*, and, more recently, a stage of the *Tour de France* and the departure of the *La Vuelta a España 2025.*

In 2022, the Piedmont region supported over 800 sport events at different scales - from international competitions to local events - producing a total estimated impact of €310 million [14]. Among them, major international events such as the Giro d'Italia and the Nitto ATP Finals produced particularly striking returns. Beyond the direct and indirect financial flows, these events also contribute to enhancing the well-being of the local community, fostering participation in sport, and strengthening the international visibility of the territory.

At the same time, the sports industry is increasingly confronted with the environmental challenges generated by its activities, from greenhouse gas emissions linked to transport, to resource consumption for facilities and event logistics. This duality - between its cultural and economic benefits and its environmental footprint - has accelerated the push for more sustainable event management. As Jones claims, the events industry is rapidly transitioning towards sustainability under the combined pressure of audience expectations, regulatory requirements, and client demand [30]. Suppliers and contractors are now compelled to adapt, developing green solutions and tailored services that align with this transformation.

In this context, sport events play a crucial role in promoting sustainability. With their scale, visibility, and strong connection with local communities, these events have the potential to minimize negative environmental impacts while also generating positive effects (economic, social, and cultural) for the host community. This rising awareness has laid the foundations for the development of international standards and guidelines.

A fundamental reference for sustainable event management is the international standard *ISO 20121:2012 Event Sustainability Management Systems [7]*, developed to help organizations reduce environmental impacts, enhance economic efficiency, and generate positive social outcomes across the life cycle of an event. Recognizing that events, by their nature, generate both positive and negative effects on local communities and ecosystems, the standard provides a flexible management framework applicable to any type or scale of event.

Structured around the Plan–Do–Check–Act (PDCA) approach, this standard helps organizations in identifying stakeholders, evaluating risks and opportunities, implementing and monitoring sustainability measures, and committing to continuous improvement. Rather than prescribing specific quantitative indicators, ISO 20121 promotes a comprehensive approach that balances the three pillars of sustainability while embedding accountability, transparency, and long-term cultural change in the planning and execution of events.

In this sense, ISO 20121 complements the life cycle perspective adopted in this thesis. By covering the entire span of an event - from planning to execution and evaluation - the standard aligns naturally with the Life Cycle Sustainability Assessment (LCSA) methodology, which is also based on life cycle thinking. While ISO provides the organizational framework for managing sustainability, LCSA offers a structured methodology for assessing impacts across the three dimensions of the Triple Bottom Line, making the two approaches mutually reinforcing.

1.3 Research Objectives

The goal of this research is to assess the sustainability performance of a sport event by identifying its impacts across the three dimensions - environmental, economic, and social - in order to highlight critical areas and opportunities for improvement. The case study focuses on the 2024 edition of the Granfondo La Fausto Coppi. At the same time, this research aims to establish a basic methodology for evaluating the impacts of small- to medium-sized sport events and to explore how such an approach can be adapted to support organizers in managing events more sustainably.

The study has been conducted using LCSA methodology because of its comprehensive nature, which gives better insight into the true impacts of processes compared to other methods discussed by scientific literature. Using the Life Cycle Sustainability Assessment methodology to assess the impacts of a sport event, it's possible to determine ways to reduce or improve these impacts in a targeted manner. This process also helps to establish a baseline that will allow for quantifying the extent to which policies and initiatives can be used to optimize the future impacts of similar sport events. The objectives of the study can be summarized as follows:

- To develop an LCSA framework based on the ISO 14040 (LCA) to assess and communicate the environmental, economic and social impacts associated with a small-scale cycling event: Granfondo La Fausto Coppi.
- To create a framework applicable in other similar events.
- To integrate the 3 dimensions of sustainability into a single framework in order to facilitate the decision-making process and communicate the results.

In this dissertation, the study begins examining the theory behind the Life Cycle Sustainability Assessment (LCSA) methodology. Subsequently, a review of the scientific literature will be conducted, focusing on environmental and economic impact assessment of events.

Chapter 3 presents the case study to be analyzed; it also outlines the methodology and key considerations for conducting an LCSA approach on the selected event. A chapter is then dedicated to the analysis of the results, addressing the environmental, economic, and social impacts separately. It highlights the most impactful areas, also in relation to the origin of the participants and visitors, and identifies the categories contributing most significantly to the overall impact.

Finally, the discussion and conclusion chapters offer a critical interpretation of the outcomes, aiming to provide an integrated assessment of the event's sustainability performance across the three dimensions. These chapters also provide a generalized and adaptable framework that can be applied to other events, reflecting on methodological limitations, and proposing recommendations for future applications of this approach.

Chapter 2

Literature review

This chapter provides the theoretical foundation for the analysis carried out in this study. It begins with an overview of the Life Cycle Sustainability Assessment (LCSA) approach, highlighting both its theoretical underpinnings and methodological structure. To offer a comprehensive understanding, the three core methodologies - Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA) - will also be briefly discussed in accordance with their respective ISO standards [4, 5, 6], illustrating how each contributes to the broader LCSA framework.

Following this, the chapter takes a look at the current research surrounding the economic and environmental impacts of sports events. It dives into how such impacts are assessed, the methodologies employed, and how different event sizes are classified and analyzed in the literature.

2.1 LIfe Cycle Sustainability Assessment (LCSA)

2.1.1 Genesis and Evolution of LCSA

In response to the increasing global awareness of the environmental, social, and economic impacts, scholars and practitioners have started advocating for more comprehensive approaches to assess sustainability. The concept of sustainable development, defined as development that meets present needs without compromising the ability of future generations to meet their own needs [57], provided the foundational goal. To put this into practice, Life Cycle Thinking (LCT) emerged as a central principle,promoting a viewpoint that takes into account the entire life cycle of a product or service [51].

Building on this principle, Kloepffer (2008) introduced the Life Cycle Sustainability Assessment (LCSA) framework in the *International Journal of Life Cycle*

Assessment as a comprehensive methodology to evaluate products and systems across all three pillars of sustainability: environmental, economic, and social [32]. LCSA was developed as a step forward from single-issue assessments, aiming to deliver a multidimensional evaluation that could support balanced and robust decision-making for businesses.

The origins of LCSA are deeply linked with the evolution of environmental Life Cycle Assessment (LCA). Initially introduced in the 1960s and later refined through the ISO 14040 and 14044 standards [4, 5], LCA established a structured approach to assess the potential environmental impacts of product systems. However, as pointed out by Hackenhaar et al. (2024), it was soon recognized that a comprehensive sustainability assessment would also need to include economic and social aspects [25].

Important steps towards this integration grew in the late 2000s, particularly with reference to the Triple Bottom Line (TBL) concept proposed by Elkington [18], which emphasizes sustainability as the balance of environmental (planet), economic (profit), and social (people) aspects. As Visentin (2020) notes, the development of LCSA stemmed from the need to bring these three pillars together within a life cycle perspective [53]. The currently accepted formulation, first articulated by Kloepffer, is expressed in the equation detailed in Figure 2.1.

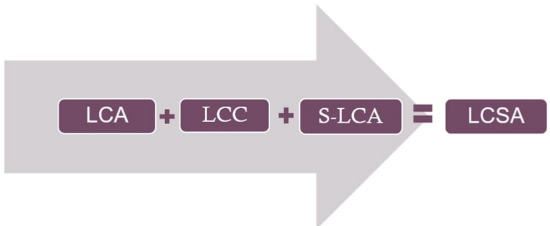

Figure 2.1: LCSA equation

This equation reflects the integration of environmental Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA). While the LCA methodology focuses on the environmental pillar of sustainability, Life Cycle Costing (LCC) and Social LCA (S-LCA) approaches were later proposed to measure the social and economic impacts. Based mainly on the same methodological steps, LCC and S-LCA have different characteristics from LCA because of their different impacts analyzed [25]. All three methods together make up a structured approach to assess the sustainability of systems according to the Triple Bottom Line. This conceptual framework was consolidated in the UNEP/SETAC Life Cycle Initiative's guidance [49], which provided methodological orientation and practical examples. Neugebauer (2015) later reinforced LCSA as one of the most advanced approaches for sustainability assessment [38].

Despite its maturity in theory, LCSA remains largely academic, with limited application in practice. As highlighted by Visentin et al. (2020), current studies provide relatively little operational guidance for practitioners, especially in terms of impact assessment and interpretation of results [53]. This gap underscores the need for further methodological development to make LCSA more actionable in real-world contexts.

2.1.2 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) represents the foundation of Life Cycle Sustainability Assessment, as it is the component fully standardized through ISO 14040 and ISO 14044 [4, 5]. Unlike the economic and social aspects, LCA benefits from decades of application in both academia and industry, where it is widely used. This consolidated tradition makes it the cornerstone of all assessment methods based on life cycle thinking, and therefore also the methodological keystone of LCSA.

LCA adopts a cradle-to-grave perspective, quantitatively assessing the potential environmental impacts of products, processes, or services across their entire life cycle—from raw material extraction to production, distribution, use, and end-of-life (recycling or disposal). According to ISO 14040, it is defined as the "compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle" [4]. To achieve this, the methodology follows four interrelated phases presented in Figure 2.2.

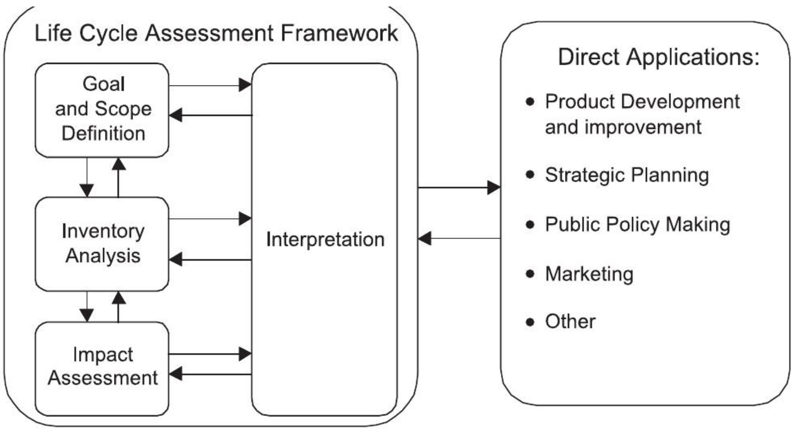

Figure 2.2: The four phases of LCA [ISO 14040:2006] [4]

- *Goal and Scope Definition*: This initial phase is fundamental to establish the context and boundaries of the study. The goal definition clarifies the intended application of the results (e.g., comparison, evaluation„ or documentation), the reason for conducting the study (such as supporting decision-making or quantifying environmental impacts), and the intended audience, which also shapes how results will be communicated.

The scope definition complements this by detailing the product system under study and the methodological choices adopted. Key elements include the description of the product system, the definition of system boundaries (e.g., cradle-to-gate, gate-to-gate, cradle-to-grave, depending on the purpose of the study), the identification of the functional unit (the quantified performance of the product system, necessary to enable comparisons), the selection of relevant impact categories and indicators, and the allocation procedures. Finally, the main stakeholder groups are identified, ensuring that the assessment remains consistent with its objectives. Further methodological details are provided in the ISO 14040 and ISO 14044 standards [4, 5].

- *Life Cycle Inventory (LCI)*: Based on the system boundaries defined in the first phase, all unit processes must be identified and described. This stage focuses on collecting data to quantify inputs and outputs, including elementary flows, always in relation to the functional unit and reference flow. The level of detail and type of data depend on the requirements established in the goal and scope definition.

  Within the broader LCSA perspective, the inventory phase expands to include not only environmental flows (resource use and emissions) but also economic data (costs and revenues) and social data, both quantitative and qualitative, linked to the relevant stakeholder groups [38].

- *Life Cycle Impact Assessment (LCIA)*: In this phase, the LCI data are translated into potential impacts across the sustainability dimensions. For the environmental pillar, the elementary flows identified in the inventory are converted into impact indicators. This process uses characterization factors provided by the selected impact assessment method to estimate the contribution of each flow, which are then aggregated into a single value for each impact category. Depending on the method applied, impacts can be expressed at midpoint level (e.g., greenhouse gas emissions) or at endpoint level (e.g., damage to areas of protection such as human health or ecosystems).

- *Interpretation of Results*: The final phase consists of evaluating the outcomes of impact assessment to draw meaningful conclusions and provide recommendations that align with the original goal and scope of the study. As illustrated in Figure 2.2, this stage is directly linked to all the previous phases, creating an iterative process: interpretation often raises new questions that may require revisiting the goal and scope definition, refining the inventory, or adjusting the impact assessment. It also allows for checking the completeness and consistency of the study in relation to its objectives.

Within LCSA, interpretation is particularly complex, as it requires synthesising results across all three pillars of sustainability. Beyond aggregating data, this stage demands explicit communication of potential trade-offs between environmental, economic, and social performance. For this reason, visualization and decision-support tools - such as dashboards or multi-criteria decision analysis (MCDA) - play a critical role in translating the findings into actionable insights for decision-makers.

2.1.3 Life Cycle Costing (LCC)

The economic dimension represents one of the three pillars of the triple bottom line, alongside the environmental and social dimensions. According to the United Nations (1987), economic sustainability refers to the capacity to sustain economic growth in the long term without compromising the needs of future generations [57].

Within the LCSA framework, the most established method to tackle this dimension is Life Cycle Costing (LCC). As Valdivia points out, LCC is a technique used to evaluate costs throughout the entire life cycle of a product or system. It can be applied for various purposes, such as a planning tool, an optimization tool, a means to identify hotspots, or to support investment choices [51]. Unlike conventional economic assessments, LCC is distinguished by its life cycle viewpoint, which aligns it conceptually with LCA and thus with the integrated methodology of LCSA.

Historically, LCC predates LCA, but it has not reached the same level of standardization. Only in specific fields, such as the construction sector, are dedicated standards available (e.g., ISO 15686-5:2008 for buildings). Furthermore, unlike the well-developed databases supporting LCA, LCC databases are still scarce outside the construction industry . Nevertheless, as Neugebauer highlights, LCC can be applied analogously to LCA to identify economic hotspots, providing valuable input for the decision-making process [38].

Many variants of LCC have been proposed in the literature, including financial LCC (fLCC), environmental LCC (eLCC), full environmental LCC (feLCC), and societal LCC (sLCC) [51]. Among these approaches, the most compatible with LCSA is Environmental Life Cycle Costing (eLCC), described by Hunkeler (2008) [26]. eLCC encompasses all costs borne by the actors in the life cycle (e.g., suppliers, producers, consumers, and end-of-life operators), avoiding overlap with environmental LCA and adopting a structure analogous to it.

Hunkeler emphasizes that eLCC follows the same four-phases as LCA: goal and scope definition, life cycle inventory, impact assessment, and interpretation (see Figure 2.2). The main distinction lies in the output: whereas LCA provides impact results in environmental units, eLCC produces aggregated monetary costs per functional unit[26]. Crucially, when LCC is conducted in parallel with LCA and S-LCA, the three assessments should share the same goal and scope definition phase, ensuring that the three approaches share the same functional unit and equivalent system boundaries to preserve internal consistency and enabling meaningful interpretation.

Recent contributions have aimed to expand the scope of Life Cycle Costing. Moreau and Wiedema (2015), for instance, suggest shifting from a limited, single-actor perspective to a more inclusive multi-stakeholder approach, which aligns perfectly with the principles of LCSA. They redefine LCC as "the sum of all value-added activities over the life cycle" [36], thereby enhancing its relevance for sustainability-oriented studies.

Overall, LCC is widely recognized as an essential complement to LCA (and S-LCA). As Kloepffer argues, sustainable products must also be economically viable - otherwise they will not be accepted in the market [32].

Despite the traditional approach to Life Cycle Costing (LCC) being widely used, Neugebauer et al. (2016) argue that it is insufficient when it comes to the broader goals of a Life Cycle Sustainability Assessment (LCSA). They believe that the conventional LCC method is too limited due to its primary focus on costs, which oversimplifies the economic aspect of sustainability. This limited, cost-driven view fails to consider the wide range of positive and negative consequences of economic activities [37]. To fill this gap, they suggest the Economic Life Cycle Assessment (EcLCA) framework, which introduces explicit economic impact pathways in accordance with the ISO 14044. This approach links microeconomic activities to macroeconomic results and identifies Areas of Protection (AoPs) - specifically Wealth Generation and Economic Prosperity - to better capture the contribution of economic processes to sustainability.

2.1.4 Social-Life Cycle Assessment(S-LCA)

The third pillar of sustainability assessment is the social dimension, which complements the environmental and economic perspectives. The integration of social aspects into sustainability assessment has developed steadily over the past three decades.

Building on the foundations laid out by ISO 14040 and ISO 14044[4, 5], Social Life Cycle Assessment (S-LCA) was developed to evaluate the social impacts of products and services along their life cycle . Recently, this approach has been formalized through the ISO 14075:2024 standard, which outlines the principles and framework for S-LCA [6]. S-LCA, when applied together with Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), contributes to the broader Life Cycle Sustainability Assessment (LCSA) framework [32].

A critical methodological requirement of LCSA is the harmonization of the three dimensions under a common goal and scope. This implies that LCA, LCC, and S-LCA studies should employ the same functional unit, product system, and system boundary to ensure consistency and comparability of findings [32].

Social Life Cycle Assessment (S-LCA) also differs from LCA and LCC in its distinctive multi-stakeholder orientation, indeed, as defined by the ISO 14075:2024, it extends the traditional LCA framework by evaluating how products and services affect different stakeholders such as workers, consumers, local communities, and society [6]. Unlike conventional LCA, which focuses on emissions, energy use, and other measurable environmental impacts, S-LCA addresses issues like labor rights, health and safety, and community well-being, thus proposing a methodology where stakeholders are central to the assessment as subject of potential impacts (UNEP,2020 [3]). As stated by Purvis et al., this approach ensures that the human consequences of production and consumption systems are recognized within a comprehensive sustainability assessment [43].

This multi-stakeholder viewpoint thus enhances the credibility and inclusiveness of S-LCA compared to purely environmental or economic assessments.

Although the methodology faces significant challenges in quantifying social impacts - since these impacts are often qualitative, subjective, and less tangible than environmental indicators - Tokede and Traverso claim that S-LCA provides a critical lens by analyzing the human dimension of sustainability [47].

Finally, S-LCA embraces the same life cycle thinking approach that structures the LCA, encompassing the four iterative phases illustrated in Figure 2.2. This methodological parallelism facilitates the integration with environmental and economic assessments while ensuring transparency and comprehensiveness. Despite the inherent methodological challenges, the development of S-LCA reflects a growing recognition that sustainability cannot be fully understood without considering social aspects, thereby strengthening the role of LCSA as a comprehensive tool for assessment and decision-making.

2.1.5 Principles of LCSA

To conclude the discussion on the LCSA framework, it is important to recognize that, despite its solid theoretical basis, the practical application of LCSA remains challenging and not yet standardized. To address these difficulties, Valdivia et al. (2021) present in the Handbook of Life Cycle Assessment a set of Ten Principles for conducting LCSA [51]. These principles have been widely agreed upon in the literature as a way to strengthen consistency, transparency, and robustness in applying the methodology.

The Ten Principles aim to provide clear guidance on how to implement LCSA in practice, covering key aspects such as alignment with ISO 14040 standards, ensuring completeness across the three pillars of sustainability, being transparent about assumptions and methods, engaging stakeholders, and clearly communicating trade-offs. Their straightforward approach makes them an effective way to summarize the main methodological challenges discussed earlier while providing a structured approach for practitioners.

For this reason, it was considered appropriate to cite and briefly discuss these principles here, as they provide a concise recap of the essential guidelines to follow when applying an LCSA framework. In this dissertation, particular attention has been given to aligning the methodology with these principles, thereby ensuring that the assessment remains consistent with the best practices established in the field.

1. *Understanding the Areas of Protection (AoPs)* – To effectively evaluate products or services across all three sustainability dimensions in a target-oriented manner, it is essential to clearly identify what is being optimized, protected, or improved. This understanding needs to be clearly articulated in the goal and scope definition. Without a well-defined target, the study would lack structure and direction. In an LCSA, the intended objectives should be established from the beginning, ensuring that any relevant pathways, impact models, and indicators are not overlooked. Practically, it is useful to start by clarifying what the study aims to achieve and then trace back to identify the process chains, stakeholders, and cost flows involved.

2. *Alignment with ISO 14040* – LCSA should follow the four phases defined in ISO 14040: (1) Goal and Scope, (2) Life Cycle Inventory Analysis, (3) Life Cycle Impact Assessment, and (4) Interpretation. Since LCA, grounded in ISO 14044, provides the methodological basis for the environmental, economic, and social dimensions, such alignment ensures coherence across all three pillars. A shared goal and scope definition guarantees consistency in defining the functional unit and system boundaries, facilitating a smoother implementation of the study and a more robust overall design.

3. *Completeness* – Completeness requires that an LCSA addresses all three pillars of sustainability. Moreover, each component study - LCA, LCC, and S-LCA - must cover the entire product life cycle or value chain within the defined boundaries, with transparent justification for any exclusions. Otherwise, the analysis cannot be considered a true LCSA. Given that the aim is not to assess one dimension in isolation but to provide a sustainability assessment across all three, completeness is fundamental for supporting decision-makers. This highlights the importance of comprehensive data collection, and where data are scarce, the limitations and assumptions must be clearly stated and explained.

4. *Stakeholders' Perspective Consideration* – The perspectives of key stakeholders must be systematically considered. No relevant or affected social group should be excluded, and the data collected in an LCSA should meet the decision-making needs of all identified stakeholders in terms of geographical scope,

level of detail, and coverage of indicators. Identifying stakeholders early allows the goal, functional unit, and system boundaries to be defined appropriately. Since each stakeholder may have different perspectives - particularly in the case of LCC - it is important to adopt a multi-stakeholder approach to ensure inclusiveness and balance.

5. *Product Utility Consideration* – Beyond the functional unit of a product, it is essential to take into account its broader utility, its overall usefulness. By clearly defining the product's core characteristics and intended use, it's possible to get a clearer understanding of its function and ensures that co-benefits are properly acknowledged. This principle emphasizes the importance of considering how the findings of an LCSA will be used, thereby strengthening the relevance and applicability of the assessment.

6. *Materiality of System Boundaries* – A well-defined system boundary is essential to ensure that all relevant and significant processes with potential impacts on one or more sustainability pillars are included in the assessment. This principle emphasizes the importance of considering the relevance of results in relation to data availability, stakeholder definition, assumptions, and limitations. Without clear boundaries, key impacts may remain unidentified, which would compromise the robustness of the study. Closely linked to the principle of completeness, materiality ensures that the LCSA remains comprehensive and focused on the most significant aspects of the product system.

7. *Consistency* – Consistency requires that system boundaries, methods, impact categories, models, data, and assumptions are applied in a coherent and non-contradictory manner. This principle is applied both within and across the three techniques (LCA, LCC, and S-LCA), allowing for meaningful comparisons and a smooth implementation of the assessment. Consistency enhances reproducibility, traceability, and comparability over time, which are crucial for decision-makers. However, challenges often arise in maintaining consistency between system boundaries and data sources, making it essential to document assumptions and methodological choices transparently.

8. *Transparency* – Transparency demands that methods, data sources, assumptions, selection criteria, and limitations are presented in an open, comprehensive, and understandable manner. Transparent reporting enables other practitioners to understand, reproduce, and validate the assessment. It also strengthens the credibility and acceptability of LCSA study, particularly for non-specialist audiences. Supplementary materials - such as detailed tables, calculations, and references - are encouraged to support traceability and clarity..

9. *Explicit Trade-Offs Communication* – LCSA studies need to clearly communicate trade-offs to ensure that decisions are made consciously, justifiably, and with balance across the three pillars. By making trade-offs explicitly, decision-makers and stakeholders can better understand the conflicting goals and the implications of prioritizing one dimension over another. This level of transparency enhances the credibility and acceptance of the results, providing a stronger basis for informed decision-making.

10. *Caution When Compensating Impacts* – Negative and positive impacts should not be directly compensated within or between sustainability pillars. Instead, they should be presented separately to avoid misleading interpretations. While integrated results such as single scores may sometimes be needed for decision-making, they should only be provided with clear disclosure of the assumptions, calculations, and weighting methods used. Focusing too much on compensation risks undermining the intrinsic purpose of LCSA, which is to offer a balanced understanding of sustainability impacts without masking trade-offs between different dimensions.

2.2 Impact Assessment of Sport Events

Now that the structure and methodology to be used - namely the LCSA framework - has been defined and thoroughly discussed, the focus shifts to its application for assessing the sustainability performance of a sport event. For this reason, this section explores the existing scientific literature on the sustainability assessment of sport events. In the pursuit of sustainable event management, according to Atescan and Yuksek, it is crucial to identify and accurately assess the environmental impacts of events [2], while also considering the economic and social effects on local communities.

A key challenge is that few events systematically measure the sustainability impacts of their activities. When assessments are conducted, they usually focus on a single dimension (environmental or economic) while overlooking an integrated perspective. Life Cycle Sustainability Assessment (LCSA), which combines environmental, economic, and social dimensions, offers a more comprehensive framework to evaluate overall sustainability performance. Although LCSA has been increasingly applied in other sectors, its use in sport events remains very limited. Moreover, most methods applied so far are tailored to a single case, making it difficult to compare results across different events. Future research should therefore aim to establish standardized approaches. As Getz argued, sustainable events require standardized measures to assess environmental impacts, but at present only financial and economic measures are well developed, while the social dimension remains the least explored and lacks consistent frameworks or evaluation methods [21].

When it comes to integrating sustainability dimensions, the Triple Bottom Line (TBL) framework introduced by Elkington [18] emphasizes the equal importance of economic, environmental, and social aspects, providing balance and coherence to the construct. However, numerous studies reveal an imbalance in practice, as some treat sustainability mainly as an environmental concern, while others prioritize the economic line. This lack of uniformity underscores the need for more comprehensive approaches, such as LCSA, which give equal consideration to all three pillars.

The term “event” spans a wide range of activities, including cultural, business, recreational, and sporting events. Context, frequency, type of participation, and scale all influence the impacts of events, making broad generalizations difficult. This dissertation focuses specifically on sport events and, within this area, on sport tourism.

To better understand the scale of events impacts, Gratton et al. (2000) proposed a typology of major sporting events, ranging from Type A to Type D, as presented in Table 2.1.

Table 2.1: Typology of sport events [24, 56]

Type A	Irregular, one-off, major international spectators events generating significant economic activity and media interest (e.g., Olympics, Football World Cup)
Type B	Major spectator events, generating significant economic activity, media interest and part of an annual domestic cycle of sports events (e.g., FA Cup Final, Six Nations Rugby Union Internationals, Wimbledon)
Type C	Irregular, one-off, major international spectator/competitor events generation limited economic activity (e.g., European Junior Swimming Championships, IAAF Grand Prix)
Type D	Major competitor events generating limited economic activity and part of an annual cycle of sport events (e.g., National Championships in most sports)
Type E	Minor competitor/spectator events, generating very limited economic activity, no media interest and part of an annual domestic cycle of sports events

This classification was later extended by Wilson (2006), who added a fifth category (Type E in Table 2.1) to include smaller-scale local events [56]. These events are often annual, with limited media coverage and modest economic activity compared to larger ones. However, they may still provide important benefits to local communities. Veltri et al. (2009) note that sport events of this type, when hosted in small or medium-sized communities, tend to generate proportionally greater economic benefits than if they were staged in larger cities [52].

2.2.1 Quantitative Methodologies for the Environmental Assessment of Events

The assessment of the environmental impacts of sport events remains fragmented, with most evaluations conducted on an ad hoc basis rather than through standardized methodologies. McCullough et al. (2023) note that the absence of common standards or benchmarks undermines the legitimacy of sustainability efforts in sport organizations. Different approaches are often employed, including Ecological Footprint analyses, input–output models, carbon footprints, and Life Cycle Assessment (LCA), but the lack of comparability across studies limits the development of a consistent evidence base. Smaller sport organizations, in particular, rarely assess their impacts due to the high costs, limited data availability, and methodological complexity, and the few that did used approaches that vary widely in scope and reporting [35]. Events by their nature are highly transitory and often exhibit non-uniform characteristics, making the study of their characteristics challenging compared to other phenomena that can be accommodated in an experimental design with control groups.

Cavallin Toscani (2021) identifies five broad quantitative methodologies commonly used in environmental assessments of events: Environmental Impact Assessment (EIA), Environmental Input–Output Analysis (ENVIO), Ecological Footprint (EF), Carbon Footprint (CF), and Life Cycle Assessment (LCA) [8]. Each method offers unique advantages and limitations. EIA, for instance, has historically been the main policy tool for assessing the environmental impact. However, its application to events has been criticized for its limited focus on direct and local impacts. Studies such as Dolf et al. (2011) show how transport-related emissions can dominate the footprint of sport events [12], yet EIA often fails to account for indirect or life cycle impacts, such as energy and material production. Collins (2012) therefore argues that this method is inadequate for events, which involve complex supply chains and indirect consequences [9].

The ENVIO approach extends traditional economic input–output models that have largely been used to assess the economic impacts of tourism and events, linking final demand for goods and services to environmental externalities generated across supply chains. While Jones highlights its value for capturing indirect impacts [30], ENVIO lacks sufficient granularity to be used as a stand-alone method. Instead, it is most effective when combined with other tools, such as hybrid LCA–IO models, as demonstrated in Kitamura (2020) [31]. This integration allows researchers to capture both direct impacts at the event level and indirect impacts from broader value chains.

Footprint methodologies - namely EF and CF - offer easily communicable indicators. The Carbon Footprint (CF) approach measures the total greenhouse gas (GHG) emissions of an event, expressed in kilograms of CO_2-equivalents. Cavallin Toscani et al. claim that, being standardized by the GHG Protocol Product Standard, CF calculations effectively represent a simplified LCA, as they cover the event's full life cycle and extend to supply chains [8]. Nevertheless, CF is limited to climate change impacts, neglecting other environmental impact categories that may be equally significant. In contrast, the Ecological Footprint (EF) provides a proxy for overall resource use and environmental pressure by estimating the biologically productive land required to sustain the event's resource consumption and absorb its emissions. Collins and Roberts (2017) describe EF as a broader indicator expressed in global hectares (gha), although its complexity makes it less intuitive than CF [10].

Among the various methodologies here outlined, Life Cycle Assessment (LCA) stands out as the most comprehensive and commonly used approach in sustainability research. When applied to sport events, LCA can capture a wide range of impact categories and track all activities throughout the entire event life cycle, from planning stages to dismantling. This holistic perspective makes LCA particularly effective at identifying the most impactful stages, but its application to events is resource-intensive and entails difficulties in collecting primary data and, ultimately, it also requires solid databases.

Despite these challenges, recent studies demonstrate the potential of LCA for sport events of different scales. For instance, Wang (2024), Edwards (2016), and Dolf (2017) [13, 17, 54] applied the LCA methodology to analyze emissions related to transport, food and beverage, accommodation, and energy and materials consumption, highlighting the predominance of attendee travel as the main contributor. Toscani et al. (2019) further advanced the field by proposing a uniform life cycle model for events, incorporating a multi-case and multi-actor perspective [48]. More recently, Atescan-Yuksek et al. (2025) emphasize the growing role of LCA in assessing the multi-dimensional sustainability of event organizations [2].

Taken together, the literature consistently shows that Scope 3 emissions - those outside the direct control of event organizers, such as those from supply chain activities and participant travel - represent the largest share of environmental impacts. Among these, participant travel to the event stands out as the dominant contributor in almost all studies [12, 13, 17]. These findings highlight both the complexity of assessing events and the critical need for standardized, life cycle–based approaches to ensure comparability and support sustainable decision-making processes.

2.2.2 Economic Assessment of Events

Compared to the environmental dimension, the study of the economic impacts of sport events is far more developed and widely explored in the literature. Lee broadly defines the economic impact of a sport event as the net change in an economy resulting from hosting the event, primarily through additional spending in the region [33]. This spending can generate substantial benefits for local communities, which explains why the economic dimension has historically received more attention than the other two pillars.

A large body of research has investigated both mega-events and small-scale competitions. For instance, Duglio and Beltramo (2017) assessed the direct economic return of a trail running event (Collontrek) with around 900 participants, highlighting the tangible benefits for the host community [15]. Small and medium-scale events, as Gibson notes, often generate net positive outcomes because they typically rely on existing infrastructure, attract visitors who might not otherwise come, and support local businesses such as hotels, restaurants, petrol stations, and shops [22]. Looking at the Mega Events, Sardi et al. (2025) examined two prestigious cycling events - the Giro d'Italia and the Tour de France stages hosted in Piedmont - showing how large-scale events can play a fundamental role in promoting sustainable tourism and revitalizing host regions [46].

From a methodological perspective, the most frequently applied framework for Economic Impact Analysis (EIA) of sport events is the one introduced by Crompton (1995) [11]. This model breaks down the economic effects into three main categories: direct effects, which capture the immediate spending linked to accommodations, food, transport, and entertainment activities; indirect effects, which result from subsequent rounds of spending by suppliers meeting the increased demand created by the event; and finally, induced effects, which reflect the changes in income and consumption levels among residents in the host area. Together, these three effects provide a comprehensive picture of how money from event-related spending flows through the economy.

In this context, various analytical approaches are used to estimate indirect and induced effects. Among these methods, input–output models and multiplier analysis are the most common [11, 46]. Input–output analysis tracks the monetary flows between different sectors of the local economy, providing a detailed account of economic linkages. However, it requires updated national or regional input–output tables and can be complex to implement. Multiplier analysis, on the other hand, is simpler and estimates the chain effects of initial expenditures by applying sector-specific multipliers. While this approach offers a more accessible way to capture broader impacts, it can sometimes lead to overestimations or inaccuracies due to reliance on assumptions about spending behavior.

In sum, economic impact studies on sport events provide a strong foundation for understanding how events affect host communities. However, they also highlight the imbalance across the three pillars of sustainability, as economic effects are far more measured than environmental or social ones. This gap underlines the importance of integrated frameworks, such as LCSA, that aim to capture the full spectrum of event impacts in a standardized and holistic manner.

Chapter 3

Methods

This research adopts a single-case study approach focused on the Granfondo La Fausto Coppi, a long-distance amateur cycling event held annually in Cuneo, Italy. The analysis specifically concentrates on the 2024 edition, which took place during the last weekend of June. This event provides a valuable case for examining sustainability in the context of sports events, given its scale, regional significance, and ongoing commitment to environmental and social responsibility.

This chapter outlines the methodological framework used to conduct the Life Cycle Sustainability Assessment (LCSA) for the event. In particular, it focuses on the first phase of the LCSA - Goal and Scope definition - which lays the foundation for the impact assessment that follows. This phase, as previously described in Chapter 2, involves clearly defining the objectives of the study, defining the system boundaries, identifying the main impact categories to analyze, and setting the functional unit. By structuring the analysis according to the LCSA framework and relevant ISO standards, this chapter provides the essential groundwork for interpreting and understanding the environmental, economic, and social impacts of the Granfondo La Fausto Coppi. The choices and assumptions made during this preparatory phase are critical for ensuring the transparency, consistency, and relevance of the findings presented in the following chapters.

3.1 Case study: Granfondo La Fausto Coppi

The selected case study for this research is the Granfondo La Fausto Coppi, one of the most iconic and long-standing amateur cycling events in Italy. Managed by the sport association *A.S.D. Fausto Coppi On The Road*, the event takes place annually in Cuneo, in the Piedmont region. With the 2025 edition marking its 36th anniversary, the event is deeply rooted in the Italian cycling tradition, taking its name from Fausto Coppi, one of the greatest champions in the history of the sport.

Widely regarded as one of the most prestigious granfondo events on the national and international calendar, the Granfondo La Fausto Coppi attracts over 2,300 cyclists from numerous countries each year, highlighting the global appeal of the event. Its international character is further underscored by the traditional *Sfilata delle Nazioni*, where flags and delegations of all represented countries are celebrated in the main streets of Cuneo.

As it's shown in Figure 3.1, the event offered three distinct routes to accommodate different skill levels and athletic goals:

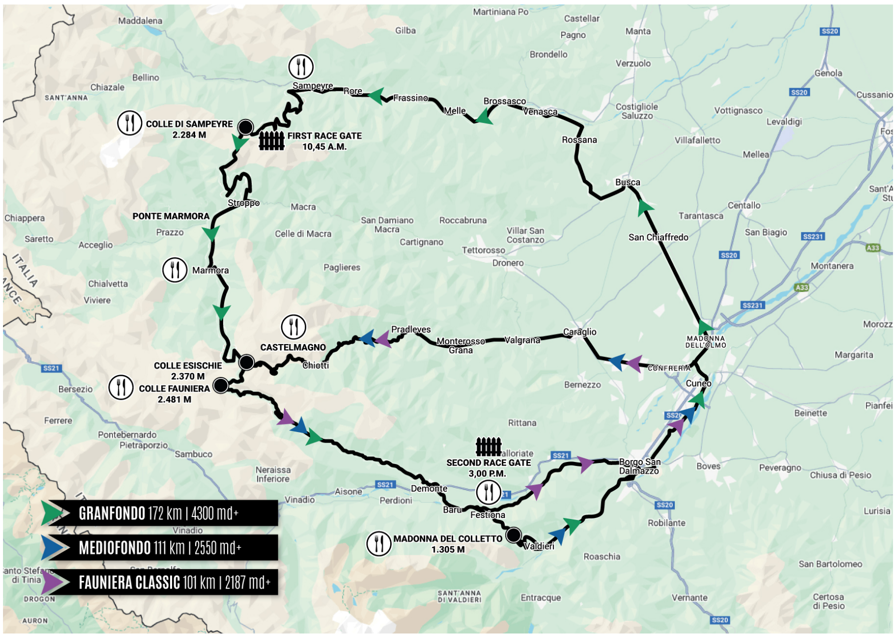

Figure 3.1: Routes of the event [23]

- *La Fausto Coppi* (Granfondo): A demanding 172 km route with 4,300 meters of elevation gain, featuring legendary climbs such as the Colle Fauniera (2,480 m), a symbolic and challenging ascent in the Cottian Alps.
- *La Mediofondo*:A shorter and equally challenging course of 111 km with 2,500 meters of elevation gain, which offers an Alpine experience without the extreme level of long-distance endurance required for the full-length granfondo.
- *Fauniera Classic* (non-competitive): A non-competitive ride that celebrates the most iconic climb of the event - the Colle Fauniera. This route is designed for cyclist who wish to experience the joy of riding in an extraordinary natural setting, without the pressure of timekeeping in a more relaxed and inclusive atmosphere.

While the main race is held on Sunday, the event itself spans the entire weekend, transforming the city of Cuneo into a festive and inclusive sports village. Activities begin on Friday with the opening of the Expo Village in Piazza Galimberti, featuring stands from sponsors, cycling brands, and local associations. This space remains open throughout the weekend and serves as the heart of event-related activities.

The program is further enriched by several side events, including social rides and a cycling event dedicated to young cyclists promoting engagement with sport and a healthy lifestyle. There are also festive parades, street food stands, and various cultural events. The analysis covers the full three-day period, from Friday to Sunday, capturing not only the experience of registered participants, but also the involvement of visitors, supporters, families, and tourists who contribute to the event's environmental, social, and economic footprint.

3.2 Research Method: Life Cycle Sustainability Assessment

This research applied a Life Cycle Assessment framework that followed the procedures laid out in the standard *ISO 14044 Environmental management - Life cycle assessment - Requirements and guidelines[5]* to quantitatively assess the major impacts of Granfondo La Fausto Coppi.

The LCSA has been conducted due to its comprehensive nature and because the methodology takes into account the indirect impacts surrounding an event, in addition to the more direct impacts that actually occurred at the event. This inclusive nature of life cycle assessments makes them well suited for determining the impact of events, which involve a large number of complicated processes.

This section, which represents the first phase of the LCSA, has crucial importance for the entire study as it constitutes the common starting point for all three dimensions in which impacts are assessed. As illustrated in ISO standards 14040–14044 (LCA)[4, 5] and ISO 14075[6], the goal and scope definition phase is the first fundamental step in an environmental, economic, and social life cycle assessment of the event. This phase establishes the context of the entire study and determines its direction and depth. A clear and well-structured definition of the goals and scope is essential to ensure that the study is relevant, coherent, and capable of answering the specific research questions for which it was undertaken.

3.2.1 Goals and scope of the study

In the context of the sustainability assessment of the Granfondo La Fausto Coppi, the primary objective is to evaluate the overall sustainability performance of the event in order to raise awareness of its current impacts and highlight areas for improvement. The analysis adopts a multi-dimensional approach, integrating Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA), with the aim of identifying strengths, weaknesses, and strategies implemented. The intended application of this study is to identify opportunities for improvement, to communicate findings to stakeholders, and to enable comparisons with different editions of the same event or with other events of similar or different scale. The motivation behind this work lies in the need to objectively evaluate the event's impacts across the environmental, economic, and social pillars of sustainability, thereby supporting continuous improvement and informed decision-making for future editions.

While the goal definition provides the study context, scope definition helps contextualize the subject of the assessment. Based on ISO 20121-*Sustainable Event Management*[7], the scope should guide the management of greater sustainability throughout the entire life cycle of the event, detailing key initiatives and the results achieved in specific areas such as waste management practices, sustainable procurement (e.g., selecting local suppliers instead of more distant alternatives), community engagement (positive impacts on the local economy), and inclusivity. Defining the scope is particularly important when conducting a life cycle assessment of events, as complex events can have far-reaching environmental, economic, and social implications, making it essential to identify the necessary information and methodological choices before starting the assessment. In this study, the scope is geographically limited to the event held in Cuneo (Italy), covering its economic, environmental, and social dimensions.

The intended audience for this study includes the general public attending the event, the organizing committee, and relevant local stakeholders, such as representatives of the Municipality of Cuneo and other community actors. Considering that most of the audience is not expected to have a technical background in life cycle sustainability assessment, the results will be communicated in a clear and accessible way, while still ensuring scientific robustness. The emphasis will be on explaining the key findings, their practical implications, and possible areas for improvement in terms that are easily understood and directly relevant to the event's context. As a consequence of this type of audience, the choice of environmental impact categories for the assessment was deliberately limited to a single indicator: *Global Warming Potential* (GWP), commonly referred as carbon footprint and expressed in CO_2 equivalent (CO_2e). This decision aligns with the observation by Dolf in his case study on a sporting event[13], who noted that while the public may be familiar with impact categories such as climate change (or GWP), others - such as eutrophication, acidification, photochemical smog, or ecosystem quality - are less well understood and challenging to communicate concisely. Events therefore tend to adopt simpler, more communicable approaches, such as focusing on carbon or ecological footprint. This study exclusively applied the GWP category for two main reasons: first, it is arguably the most widely recognized and accepted metric among the sport event industry allowing simpler comparisons; second, limiting the scope to a single impact category reduces complexity, enabling clearer communication and facilitating potential methodological improvements. In this context, the term *carbon footprint* refers to the total greenhouse gas (GHG) emissions associated with the event, converted into a common unit - kilograms of carbon dioxide equivalent (kg of CO_2e) - over a standard 100-year time horizon. This includes major GHGs such as carbon dioxide, methane, and nitrous oxide, each weighted according to its relative contribution to global warming, as characterized by the Intergovernmental Panel on Climate Change (IPCC)[27].

For the remaining economic and social dimensions, the selection of impact categories was more straightforward. In the economic assessment, all results are presented in monetary terms, allowing for direct and intuitive interpretation. For the social aspect, the assessment relies on event-specific indicators and socio-demographic data, for instance, participants' rate of return, satisfaction level, and community engagement. These indicators, while not strictly framed as "impact categories" in the LCA sense, offer a clear and measurable representation of the social outcomes of the event.

3.2.2 Functional Unit and System Boundaries

The functional unit (FU) used is *"preparation and execution of a 3-day sports event with 2,300 participants held in the province of Cuneo"*. This FU fully complies with the standard definition since it clearly defines the function by specifying what is delivered, the quantity, and the location. This ensures that the assessment is based on consistent performance criteria, enabling meaningful comparison with other similar systems.

It is important to note that the number of participants stated in the functional unit indicates the event's size, facilitating comparisons with other events of similar scale. However, to provide a more comprehensive analysis and highlight the event's impact on the local community, this study also includes all visitors attending the event alongside the registered participants. By participants, it's meant those who officially register and pay a fee, but naturally, visitors accompanying them are also present. These visitors have been included in the study and will be analyzed throughout the different phases. As shown by the results in Chapter 4, there is a correlation between participants' origin and the number of visitors; for this reason, expanding the analysis to include visitors as well as participants was considered essential.

In addition to the total impact of the event (total economic impact and total kg of CO_2e generated), the results Chapter will also present the impact per attendee, such as daily average expenditure per person and kg of CO_2e emitted per person. This approach highlights the correlation between participants' origin and both economic and environmental impacts, while also facilitating potential benchmarking with events of different sizes.

The system boundaries for this analysis are defined to establish a clear and consistent framework aligned with the study's goals. The product system under study follows a cradle-to-grave approach, including five areas of analysis, as illustrated in Figure 3.2.

Figure 3.2: Product system: cradle to grave approach

To focus the assessment and maintain coherence across the environmental, economic, and social dimensions, three specific boundaries - geographical, operational, and temporal - are applied, following the methodology suggested by Piccerillo et al [42]:

- The geographical boundary limits emissions and impacts to those generated within the province of Cuneo, including only transportation and activities occurring inside this territorial scope.

- The operational boundary includes direct and indirect impacts related to the main areas of activity of the event, as represented in the flow diagram in Figure 3.2.

- The temporal boundary limits the analysis to approximately three days, which is the duration of the event itself.

These boundaries serve to simplify the system under study by excluding elements that would excessively broaden the scope and risk diluting the relevance of the analysis, ensuring a focused and manageable evaluation consistent with the defined goals.

3.3 Data Collection Methods

Given the complexity and the breadth of the study - which involves the analysis of several categories such as food, materials and travel for thousands of people - makes the sport events particularly challenging to assess impacts. Quantitative information, such as the number of attendees and visitors, distance traveled, daily expenses, amount of food consumed and waste generated, can be difficult to determine. Acquiring such information requires a strong partnership with the entities organizing and planning the event. It is important to identify what information will be needed before starting the assessment, as this helps ensure all the necessary data are collected. This section describes the data collection methods to gather all the inputs and outputs of the unit processes identified by the product system and to analyze each dimension of impact.

Data for this study were collected in four different ways. First, a questionnaire was sent to participants to gather primary data about travel patterns, spending behaviors, and other relevant details. Second, registration data from the last four editions of the event (2019, 2021, 2023, and 2024) were analyzed to identify trends and participant characteristics over time, including their birth dates, gender, country, and city of origin. Third, semi-structured interviews were conducted with the event organizers and key stakeholders involved in planning and execution of the event, providing qualitative insights into operational practices and decision-making processes. Lastly, in cases where primary data were unavailable or infeasible to collect, secondary data were sourced from scientific literature and established databases to ensure the completeness of the analysis.

With regard to the questionnaire, it was distributed through the official social media channels of the event's organization. The questionnaire was available in Italian (a copy is provided in Appendix A), English, and French, and was targeted exclusively at participants of the event. To encourage a high response rate and avoid overburdening respondents, the questionnaire was designed to be as concise as possible. For this reason, only closed-ended questions were included, enabling faster completion and minimizing potential response errors. The questionnaire consisted of four sections:

- Socio-demographic data collected to compare the sample of respondents with the official registration data of participants, in order to assess the representativeness of the sample.

- Social impact questions regarding past participation in the Granfondo La Fausto Coppi, including specific editions attended and overall satisfaction level.

- Transport and accommodation questions about travel distance and mode of transportation, number of visitors accompanying each participant, type of accommodation, and length of stay.
- Questions on participants' spending patterns categorized by different types of expenditures. Here, spending was presented in predefined ranges rather than asking for exact numbers, reducing the effort for respondents and limiting potential errors.

The survey was crucial to this study as it represented the main source of primary data. Beyond providing key results, it also yielded valuable insights, such as correlations between participants' place of origin and the number of accompanying visitors, or between origin and average daily expenditure. These details enriched the overall analysis with meaningful trends. The survey link remained active for seven days, during which a total of 176 responses were collected.

Regarding the registration data, these were provided as Excel spreadsheets containing information such as age, gender, nationality, and city of origin for all registered participants of the last four editions of the event (2019, 2021, 2023, and 2024). Each edition involved approximately 2,300 participants. These datasets were fundamental for calculating travel distances, which - combined with the survey results - were later used to estimate transport-related emissions. Furthermore, the registration data were also employed to assess the event's social impact indicators.

As shown in Table 3.1, the distribution of respondents closely matched that of the participants in the 2024 edition. In particular, the age distribution, gender, and distance categories - divided into local, national, and international groups - were largely similar between the two samples. This similarity lends credibility to the collected sample, which therefore is assumed to be representative of the population. More specifically, each group can be considered representative of its corresponding segment, allowing to highlight potential differences in behavior according to participants' origin. A more detailed discussion of these findings will be provided at the beginning of Chapter 4.

As for literature and databases, scientific studies were consulted, particularly when the methodological approach adopted by the authors closely matched the nature of this research. These external studies, and the specific datasets derived from them, are discussed in detail in Chapter 4 whenever they were used to complement or support this study's findings.

In terms of databases, most were used for environmental and economic impact assessment. Specifically:

- Ecoinvent 3.9.1: a widely used collection of life cycle inventory (LCI) data for environmental assessments analyzed using the OpenLCA software. It provides

Table 3.1: 2024 Participants and Survey Results

Participants 2024			**Survey of participants**		
Age distribution			**Age distribution**		
Age group	N	% of total	Age group	N	% of total
19–25	92	4.0	19–25	6	3.4
26–40	684	29.7	26–40	52	29.5
41–60	1234	53.7	41–60	87	49.4
60+	290	12.6	60+	31	17.6
Total	2300	100	Total	176	100
Gender distribution			**Gender distribution**		
Gender	N	% of total	Gender	N	% of total
Male	2065	89.8	Male	158	89.8
Female	235	10.2	Female	18	10.2
Total	2300	100	Total	176	100
Distance distribution			**Distance distribution**		
Category	N	%	Category	N	%
Local (<100 km)	1351	59	Local (<100 km)	100	57
National (100–600 km)	602	26	National (100–600 km)	49	28
International (>600 km)	347	15	International (>600 km)	27	15

LCI data across Europe with over 4,000 datasets in areas including transport, energy supply, materials, and agriculture.[16]

- Agribalyse 3.2 (French database), which contains environmental data for both individual ingredients and prepared food products, and, importantly, it provides a breakdown of each production phase - including transport - allowing easier adaptation to the context of this study [1]. A complete list of food items modelled, along with their Agribalyse codes, is provided in Appendix B.4.

- National statistical datasets and country specific databases, cited throughout the Chapter 4 where applicable.

It should be noted that the use of these databases and software inevitably introduces a certain degree of uncertainty. This is due to the fact that most of the data are secondary, they may not be perfectly regionalized to the geographical context of this study, and are often based on international averages. Moreover, the correct use of

Ecoinvent and Agribalyse requires substantial expertise in LCA modeling, and the lack of perfect representativeness can affect the overall data quality. Nevertheless, these tools were deemed the most appropriate and efficient means to achieve the intended scope and audience of this study.

3.4 Methodological Implications

This section is included in the methodology chapter to clearly outline the main assumptions, limitations, and scope boundaries that underpin the present study. Providing this review is essential before moving to the next chapter, as it ensures the approach adopted to be transparent and that the results can be interpreted in light of the methodological choices made. The discussion reviews some of the key decisions described earlier in this chapter - decisions often shaped by the necessity of balancing the desired accuracy of results with the feasibility of data collection and assessment. While these choices allowed the study to be completed under practical constraints, they inevitably introduce limitations that must be acknowledged. The section therefore addresses the key assumptions made during the study design level, the main methodological and contextual limitations encountered, and the constraints imposed by the available data or tools. Recognizing these factors provides a more detailed understanding of the findings and clarifies the extent to which they can be generalized.

While Life Cycle Sustainability Assessment can be an effective tool for examining and comparing environmental, economic, and social impacts of different events, it is important to note that collecting the data necessary for such assessment can be challenging. Much of the needed data is not readily available, and as a result, some of the methodologies used in the study were flexible and adaptive in order to document the impacts as thoroughly as possible.

The research distinguishes two types of data:

- Primary data that are specific data collected directly from the value-chain actor either on site or via surveys, interviews and measurements.
- Secondary data that are generic data taken from literature or databases.

The collection of primary data is highly dependent on the relevance of the respective data and the effort required to collect it, the intended use of the LCSA results, and the intended audience[51]. Generally, primary data collection is prioritized for the foreground system, while the background system can be modeled with secondary data. However, in this study, due to limited human resources (as the data collection was carried out by a single researcher), the extensive scope of the analysis covering three sustainability dimensions, and the inherent difficulty of obtaining primary data for small to medium-sized events, part of the foreground system - especially in the environmental assessment - was modeled relying on secondary data from databases or literature. This methodological choice was made to streamline the study while remaining consistent with its intended application and audience. Additionally, if there are significant differences in the input data, high precision is not essential, as modest variations in the data do not alter the overall ranking of the results, meaning that precise judgments can be drawn even from less precise data.

Another relevant methodological implication of this analysis lies in the close collaboration with the event organizers, whose extensive experience in the sport industry gave fundamental support to the analysis. In many of those cases of incomplete or lack of quantitative data, assumptions were made in direct consultation with the organizing team. Their deep knowledge of both the structure of the event and its connection with the regional territory offered valuable insights. This experiential understanding not only served to validate the results but also as a point of reference for determining whether outcomes aligned with patterns observed in previous editions. Given the organizers' long-standing experience and passion for the event, it was deemed appropriate and necessary to keep them updated continuously throughout the process. Their feedback was actively sought whenever results required interpretation or when reasonable assumptions had to be made. This ongoing consultation enabled a more grounded and context-aware approach, ensuring the analysis focused on the most relevant phases of the event.

While relying on qualitative input introduces a limitation in terms of objectivity and replicability, it ultimately strengthened the study by ensuring that the findings reflected not only the data available but also the practical knowledge gained from many years of organizing the Granfondo La Fausto Coppi.

Another limitation concerns the choice of impact categories for the environmental assessment. This study considered only greenhouse gas emissions, measured as Climate Change or Global Warming Potential (GWP), while other environmental impact categories - although equally important - were excluded. Including them would have required specialized LCA expertise as well as significant effort in collecting suitable data. As highlighted in the literature by Dolf [13], small to medium-sized event organizers rarely possess the technical skills necessary for a full LCA, and both staff and the public are generally more familiar with climate change than with other environmental impact categories. For these reasons, the present study focused solely on Climate Change, as it is the most widely recognized by sport managers and allowed for a clearer and more manageable methodological application in the event context. Moreover, Cavallin Toscani et al. [48] showed in the case study of a music concert that the carbon footprint is a good indicator not only of the effect on climate change, but also of the total environmental impact of an event, comprising other impact categories. Although this result needs further testing and generalization, if a comprehensive LCA considering many impact categories is not possible, an environmental impact assessment limited to climate change category represents a good trade-off.

Further important methodological constraint arises from the system boundaries defined in this study. While these boundaries provide a clear and replicable structure, they also imply a significant simplification. In particular, the chosen geographical boundary - limited to impacts occurring within the Province of Cuneo - represents a strict limitation that inevitably excludes potentially relevant insights which, in this case, fall outside the scope of the study. More critically,this geographical boundary inevitably omits - or at best underestimates - the most significant environmental burden: transport emissions occurring outside the provincial limits. This means that participants traveling from other regions or even from abroad by using planes are assumed to generate carbon emissions only within the Province of Cuneo. As discussed in Chapter 2, transportation represents the main contributor to the event's total environmental impact [13, 17, 42]. However, it was deemed necessary in order to remain consistent with the defined study boundaries. Similar to challenges reported in previous studies, most of these travel-related emissions would fall under Scope 3 emissions, which researchers may choose to exclude. For illustrative purposes, Chapter 4 includes a dedicated subsection quantifying the impact of travel distance beyond the provincial boundary - though these results are not incorporated into the final environmental impact - to provide context on the magnitude of this category.

Finally, one of the main assumptions behind this study, and important to highlight before diving into the results, is that the sample obtained through the survey, consisting of 176 respondents, is considered representative of the entire population at the event. This assumption enabled the study to extrapolate the overall impacts for the entire event, aligning with the defined functional unit. However, it also introduces a significant limitation and source of uncertainty that should be carefully considered when interpreting the results and drawing conclusions or recommendations.

To lend more credibility to this assumption, the research stratified participants into groups based on their distance of origin. This segmentation ensured that the sample within each distance category was representative of that subgroup, avoiding the aggregation of heterogeneous behaviors and impact patterns. For example, it acknowledges that local participants tend to have different behaviors and environmental impacts compared to those coming from farther away. This approach helped maintain the validity of the analysis by capturing such relevant variations within the participant population.

More generally, given the broad scope of this analysis, a number of assumptions and simplifications - some of which are quite significant - were necessarily made throughout the study. These were carefully considered and thoughtfully implemented to ensure that the results would retain relevance both for effective communication to the public and for scientific rigor. The methodology was designed to be context-specific yet adaptable, allowing easy replication for future editions of the same event, and, with appropriate caution, for similar sporting events elsewhere.

In essence, this work offers an approximate but structured application of the Life Cycle Sustainability Assessment (LCSA) framework, as outlined by ISO standards, specifically designed for sport events.

Chapter 4

Results

This chapter presents the outcomes of the analysis conducted in this study. Following the comprehensive methodological framework detailed in Chapter 3 - where the context of the event was introduced, and the Goal and Scope definition was carried out — this section moves from theory to evidence.

The results are provided according to the three dimensions of impact: environmental, economic, and social. Prior to examining the specific impacts, an initial section is dedicated to profiling participants and visitors in order to provide a common baseline of data applicable across all the dimensions of the analysis.

In addition to the general assumptions and limitations outlined in the previous chapter, this section will also highlight and justify the specific assumptions and simplifications made within each individual phase of the analysis. These choices were necessary for processing the available data, addressing unavoidable gaps, and ensuring that the results obtained are both meaningful and interpretable within the context of the event. By explicitly stating these considerations, the chapter aims to enhance transparency and allow readers to fully understand the basis upon which the results are derived.

The results presented here are based on an extensive use of the data collected, as outlined in the data collection process. Where relevant, the origin of the data will be specified - whether from participant survey, official databases, registration files from the 2024 edition, or directly provided by the event organizers. In certain sections, the analytical steps leading to the results are explicitly detailed to illustrate critical calculations and methodological choices. In other cases, intermediate steps are omitted to maintain a clear and readable flow, avoiding an overly technical narrative. For readers seeking greater insights into the detailed calculation procedures, further supporting material for this chapter is provided in Appendix B. This approach ensures that the presentation remains accessible while preserving traceability for those wishing to engage with the underlying data in depth.

4.1 Analysis of participants' and visitors' profiles

This section sets the foundation for the impact analysis, providing a shared baseline across the environmental, economic, and social dimensions. It focuses on the characterization of participants and visitors in terms of numbers, distance of origin, and length of stay. These estimates were obtained through a careful analysis of survey responses, scaled to represent the total number of participants in the 2024 edition of the Granfondo La Fausto Coppi.

The analysis presented here includes the segmentation of participants based on their distance range, the calculation of average length of stay, and the estimation of total overnight stays and total attendances. These results, directly derived from data reported in Table 3.1, are essential for the subsequent assessment of impacts.

The key assumption underlying the entire approach, as previously discussed in Chapter 3, is that the survey sample is representative of the total population of participants in the 2024 edition. To strengthen this assumption, participants were segmented into seven detailed distance-based groups and, also, into three broader categories - locals, nationals, and internationals - depending on the level of granularity required by the analysis. It should be noted that these labels are indicative: they refer solely to distance ranges rather than to the actual nationality of the participants. For example, “locals” include only those residing within 100 km of the event location, and their behavior is assumed to be represented exclusively by survey respondents falling into this distance group.

By structuring the sample in this way, it was possible to derive the average behavior for each group and extrapolate it to the total population belonging to the same category.

To maintain clarity, only the relevant findings are reported in the tables presented in this section, while the detailed procedure to calculate the distance of origin is provided separately in the Appendix B.1.

The distribution of participants in the 2024 edition, classified by distance from Cuneo, is presented in Table 4.1. The breakdown was first made into seven detailed categories to provide finer insights (upper part of the table) and then into the three broader groups previously introduced: locals (within 100 km), nationals (100–600 km), and internationals (above 600 km). The largest group by far is represented by local participants, who accounted for 1,351 out of the 2,300 total.

The survey also collected information about the number of visitors for each participant. As expected, local participants reported the highest value, averaging 1.56 visitors per participant, and reaching 1.88 for those living within 50 km. This value decreases progressively as the distance of origin increases, which is consistent with the lower likelihood of friends or relatives traveling long distances to attend the event. By scaling these values to the total registered participants, it was possible

Table 4.1: Participants and Visitors by distance distribution

Distance Distribution	Participants	Visitors per participant	Visitors	Total attendees	Avg Distance [km]
0-50 km	993	1.88	1,865	2,858	16.7
51-100 km	358	0.65	234	592	73.5
100-300 km	491	0.69	337	828	171.4
300-600 km	111	0.50	56	167	427.8
600-1000 km	89	0.38	33	122	798.3
1000-2000 km	177	0.53	94	271	1,285.8
Over 2000 km	81	0.50	41	122	8,232.2
Total	**2300**				
Local (<100 km)	1,351	1.56	2,108	3,459	31.8
National (100-600 km)	602	0.63	381	983	218.7
International (>600 km)	347	0.56	193	540	2,782.3
Total	**2300**				

to obtain an estimate of the overall number of visitors and, consequently, the total number of attendees (participants + visitors) by distance distribution.

Finally, the table also reports the average distance traveled for each category, calculated using registration data. Local participants, who represent more than half of the total, traveled on average 31.8 km, largely reflecting the concentration of attendees from Cuneo and surrounding municipalities. On the opposite side, the internationals show a significant higher value: the 122 attendees (including 41 visitors) belonging to the category "Over 2000 Km" traveled an average of 8,232 km. Unlike the other categories, where average distance increases in a more gradual and linear trend, this sharp discrepancy is explained by the presence of participants arriving from other continents, which significantly raises the group's average distance.

Table 4.1 reports an estimated total of 4,981 unique attendees, of which 2,681 were visitors. Beyond the total number of attendees, another key parameter for assessing the event size is the total number of presences over the three days. This value was obtained by combining attendees with the average length of their stay. These results are presented in Table 4.2.

Although the majority of presences were concentrated on the race day (the last of the three days), the participation of people traveling from distant locations, together with the presence of side events throughout the weekend, meant that many attendees stayed in the area for more than one day.

Table 4.2 summarizes the main findings derived from the survey. These results are particularly relevant for the following sections, especially in measuring the accommodation impacts.

Table 4.2: Average stay of participants

	Average stay [Nights]	Average overnight stays [Nights]*
Local	0.12	1.0
National	1.67	2.0
International	3.33	3.3

Percentage of overnight participants	41%
Average overnight stays [Nights]*	2.3
Total attendances	**7,138**

*Average stay of participants who actually sleep in accommodation facilities.

As expected, local participants recorded a shorter average stay of just 0.12 nights, reflecting the fact that most of them did not stay more than one day in the event area, with only a small share staying for a single night. By contrast, international participants showed an average of 3.33 nights, often exceeding the actual duration of the event. This highlights not only the sportive significance of the competition but also its cultural and touristic appeal, as many attendees take the opportunity to visit the surrounding territory during their stay.

Overall, 41% of participants reported at least one overnight stay. Based on these data, the total number of attendances over the three days is estimated at 7,138, compared to 2,300 participants.

4.2 Environmental Impact

The environmental impact assessment of an event, as discussed in Chapter 2, represents a dimension frequently studied and standardized in the scientific literature. This type of analysis is also the one that best aligns with the ISO standards for Life Cycle Assessment (LCA)[4, 5]. Accordingly, the study follows the typical steps of an LCA in a structured manner. After addressing the goal and scope definition in the previous chapter, this section proceeds with the life cycle inventory (LCI) for each area of analysis, followed by the impact assessment phase, which - consistent with the scope defined earlier - focuses exclusively on the impact category of climate change, measured through CO_2e emissions. Finally, the interpretation of results is carried out both within each category of analysis and revisited in Chapter 5 during the overall discussion of findings.

A distinctive element of this study is the introduction of a scenario analysis. For each category, two contrasting scenarios are proposed: a worst-case scenario (conservative), and a best-case scenario (optimized). This comparative approach allows the research to highlight potential areas of improvement and the extent to which sustainable practices can reduce emissions. Moreover, it provides sensitivity to the analysis, adding robustness and reliability to the results despite the inherent uncertainty of data. Simply reporting a single value could be misleading or insufficiently representative of reality. Instead, presenting a range of possible outcomes illustrates how organizational and participant practices can significantly influence the environmental performance of the event.

In the following sections, the five categories of analysis, defined by the system boundary in Figure 3.2, are examined individually, following the steps outlined above.

4.2.1 Transport

According to the scientific literature, transport represents the category with the highest environmental impact, accounting for the biggest share of the total footprint. Since transport is closely linked to the travel mode, it is crucial to assess the CO_2e emissions resulting from participants' mobility.

In line with the goal of the study, a geographical boundary was introduced as stated in Chapter 3. Only the emissions generated within the Province of Cuneo were considered, corresponding to a 75 km radius from the city of Cuneo. This assumption reflects the idea that the organizing committee can exert some degree of influence on mobility within this area, for example by promoting shuttle services for local participants and visitors.

Consequently, participants traveling from beyond this boundary were assigned a standard distance to represent the emissions accounted for once they entered the 75 km zone. This choice ensured methodological consistency with both the economic impact assessment and the other categories of analysis and emphasized the areas where the organization could realistically implement improvement strategies. At the same time, in order to provide a comprehensive picture, the results are also presented without the geographical constraint, thus capturing the full variability associated with participants' origins and travel modes.

The registration spreadsheets analyzed in the beginning of this chapter showed that a total of 1,805 participants traveled from beyond the 75 km threshold, of which 1,128 were athletes and 677 were visitors. For these individuals, the standardized distance of 150 km was applied, including also the return trip. A dedicated subsection presents the analysis of transport within the geographical boundary, while another reports the results of the overall scenario without restrictions.

The estimation of transport emissions followed the same approach as Dolf [13]. Registration data were used to calculate the person-kilometres for each distance range, while the survey data provided information on the distribution of travel modes and vehicle occupancy rates. In particular, respondents were asked not only about the means of transport used, but also how many passengers were in the vehicle in addition to the driver. This enabled the allocation of person-kilometres (pkm) across different transport modes (e.g., car, train, bus) and the application of the corresponding emission factors shown in Table 4.3. For instance, if 60% of participants within the "0-50 km" range reported traveling by car, then 60% of the total person-kilometres in that category were assigned the emission factor of private cars.

The system boundary of transport included also the return travel from the event location to the city of origin, assuming symmetrical distances. Internal movements during and within the event were excluded, as it was not possible to quantify their frequency or distances traveled, and such trips would have accounted for only a negligible share of the total impact. Their inclusion would have required an on-site survey during the event, which would have considerably enlarged the scope of the study. Similarly, secondary trips such as transfers from airports or additional movements by use of public transport means were not considered in the boundary.

In the assessment, visitors' trips were also included. This choice ensured consistency with the methodology and avoided underestimation of emissions. Indeed, occupancy rates derived from the survey represented vehicles often shared between participants and visitors.

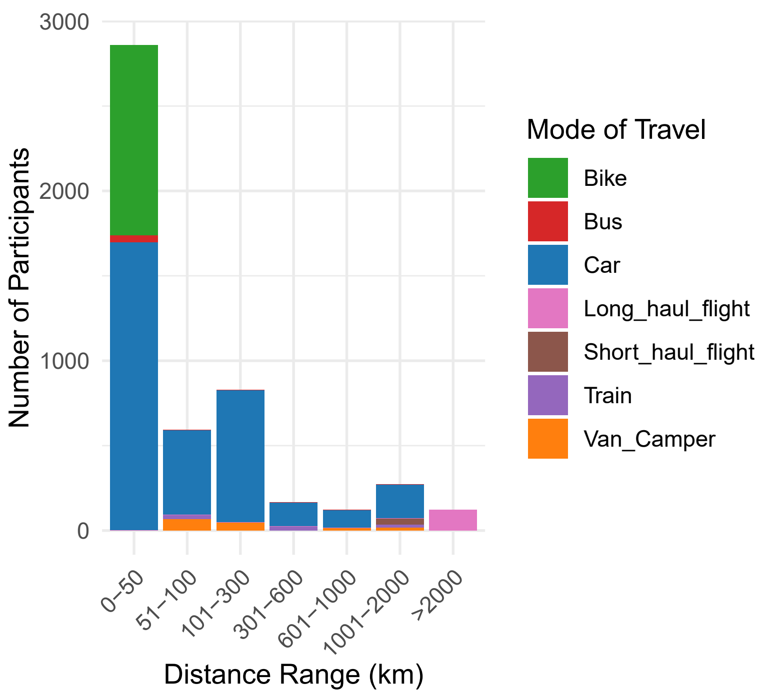

Figure 4.1: Travel Mode Distribution by Distance Range

The modes of transport considered in the analysis included bikes, cars, vans/-campers, buses, trains, short-haul flights, and long-haul flights. For the car category, a single generalized type was adopted rather than distinguishing between different sizes or fuel types. This choice made it possible to apply an average emission factor (EF) representative of the overall category.

Based on the survey results regarding the modes of travel for each distance category, and assuming that the sample for each range of origin is representative of the total number of participants and visitors from that distance, Figure 4.1 illustrates the distribution of attendees according to both their distance of origin and the means of transportation adopted. The histogram clearly highlights that the car was by far the most commonly used means of transport. A notable exception is represented by the 39% of participants coming from nearby municipalities (0–50 km), who chose to reach the event by bike.

For participants who came from greater distances, the car remained the dominant travel option, followed by a significant share of vans and campers. Finally, as expected, the figure shows that all attendees traveling from beyond 2,000 km relied on air travel as mode of transport, with long-haul flights covering this range.

Table 4.3: Emission factors by travel mode (Well-to-Wheel)[45]

Mode of travel	**Emission factor (WTW)**	**Unit**
Car*	0.193	$kgCO_2/vkm$
Van/Camper	0.231	$kgCO_2/vkm$
Short-haul flight (<700 km)	0.234	$kgCO_2/pkm$
Long-haul flight (>700 km)	0.182	$kgCO_2/pkm$
Train	0.017	$kgCO_2/pkm$
Bus	0.102	$kgCO_2/pkm$
Bike	0	$kgCO_2/pkm$

* Car emissions are calculated for an average vehicle with typical occupancy rate.

To assign carbon emissions to each travel mode, Table 4.3 reports the emission factors (EF) adopted in this study. Consistently within all travel modes, only well-to-wheel (WTW) emissions are considered - i.e., the operational ("use phase") emissions arising from fuel production and distribution (well-to-tank, WTT) and from fuel combustion during use (tank-to-wheel, TTW). Vehicle manufacturing and end-of-life are excluded to maintain coherence with the rest of the transport analysis focused on fuel consumption. An obvious implication of this boundary choice is that cycling carries an emission factor equal to zero. WTW emission factors for each mode were sourced from certified databases [45] and applied as averages across many technology variants. All factors in Table 4.3 should be interpreted as mode averages: real-world impacts can vary with technology, energy source, vehicle size, and especially occupancy for shared modes (planes, trains, and buses). To avoid false precision, the analysis deliberately refrains from over-specifying these parameters and uses representative national averages.

Travel impacts were modeled following Dolf's formulation [13] reported here:

$$I = d * \left(\frac{EF_{vkm,m}}{VO_m} \right) \tag{4.1}$$

Where I is the impact in kg of carbon dioxide equivalent (CO_2e); d is the distance in km; *EFvkm,m* represents the emission factor expressed in CO_2e per vehicle-km for the corresponding travel mode (m), and *VOm* the average vehicle occupancy rate in passengers per vehicle. Equivalently, the ratio of emission factor per vkm over the vehicle occupancy of that mode can be expressed as an emissions factor per person-km, *EFpkm,m*, such that impact is modeled by:

$$I \;=\; d * EF_{\mathrm{pkm},m}. \tag{4.2}$$

A key specification concerns the vehicle occupancy rate. For collective modes of transport such as trains, buses, and airplanes, the emission factors reported in Table 4.3 are already expressed in $kgCO_2e/pkm$. This is because, for these modes, databases typically provide values that incorporate an industry average occupancy rate, usually based on national statistics.

In contrast, for cars and vans/campers, the occupancy rates were calculated directly from the survey responses. The results indicated an average of 1.73 people per car and 2.15 people per van. While these values fall within national averages, they are lower than those observed by Dolf [13] for the *Special Olympic Games* in Canada, where the average of 2.7 people per vehicle was recorded.

As will be further discussed in the following sections, the occupancy rate represents a critical parameter in modeling travel impacts and in identifying potential strategies to reduce the environmental burden of transportation. Indeed, as introduced previously, to provide sensitivity to the analysis and highlight possible areas for improvement, a scenario analysis will be conducted. Within this category, the vehicle occupancy rate will serve as key variable distinguishing the best-case scenario from the worst-case scenario.

Overall Transport Emissions (without geographical boundary)

The following paragraph presents the results of the transport emissions analysis without applying the geographical boundary constraint. This choice was made for transparency, in order to highlight insights about means of travel and environmental impacts.

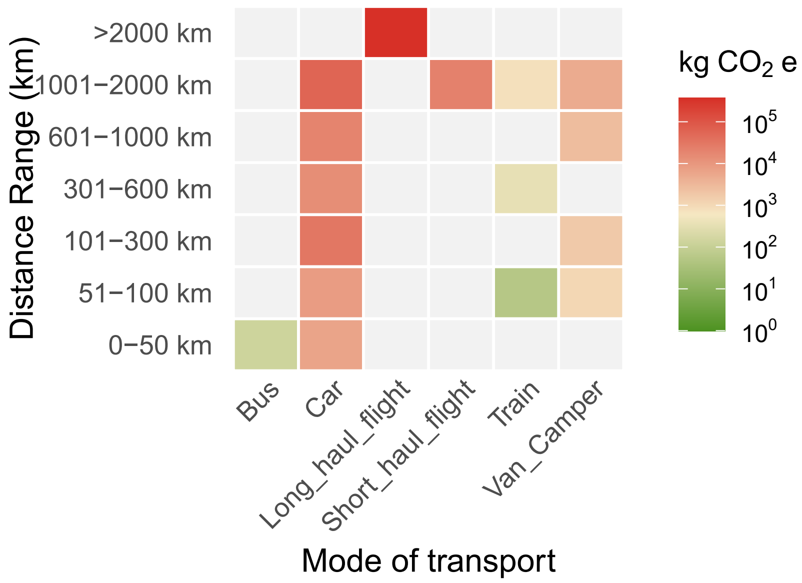

Figure 4.2: Impacts per distance and means of transport

Figure 4.2 shows the heatmap that illustrates the relation between participants' distance of origin, mode of travel, and their respective CO_2e emissions. It is clearly visible that long-haul flights for participants coming from more than 2000 km represent by far the largest contribution to total emissions. As expected, the total emissions increase consistently with the travel distance. Readers interested in detailed data can refer to Appendix B.2, where all person-kilometers for each distance range and mode of transport, along with their associated impacts, are reported.

The total emissions associated with transport, without any geographical restriction, amounted to *531.8 tonnes of CO_2e*. Of this, 68.5% was generated by long-haul flights (i.e., participants traveling from distances greater than 2000 km), followed by 25% of total emissions from car use, which was the most widespread travel mode. Although the group of participants coming from over 2000 km represented only a small share of the total sample (an estimated total of 122 participants and visitors), the significant higher average distance of origin (8232 km) led to an exceptionally higher amount of person-kilometers compared to other categories, and consequently to a higher impact.

This result shows that transport emissions are by far the most dominant category when considering international participation. Such findings are consistent with the literature, as transport belongs to the Scope 3 emissions and is expected to show the highest values, especially in the context of international events. However, it is important to underline that these emissions are largely beyond the control of the event organizers. For this reason, the geographical boundary was introduced in the subsequent analysis, focusing on the Cuneo area. This approach allows the study to concentrate on a more manageable scale, to mitigate the overwhelming dominance of transport emissions in the overall balance, and to identify realistic improvement opportunities within the local context.

Transport emissions within the geographical boundary

In this part of the analysis, the geographical boundary is applied in order to focus on the impacts that fall within the province of Cuneo, as previously presented. The boundary is defined as a radius of 75 km distance from Cuneo (i.e., 150 km in total round trip), and it includes the movements of the 1805 participants and visitors who came from beyond this threshold.

Following the same methodological approach described earlier, participants and visitors are now classified according to slightly different ranges of origin, as reported in Table 4.4:

- 0–50 km - identical to the previous classification, with the same distribution of transport modes
- 50–75 km - assumed to have the same proportional distribution of transport modes as the original 50–100 km range
- beyond 75 km - all remaining attendees, to whom the geographical boundary is applied.

An important methodological note to consider is how participants and visitors coming from distances greater than 75 km are treated. Since it would not have been credible to consider the use of air flights for distances of that magnitude, the analysis assumes that their mode of transport distribution is identical to that of the 50–75 km category. Although this represents a strong assumption, it is justified by the purpose of the boundary: to assess a geographical area where event organizers have an actual capacity of influence and propose mitigation strategies. Including air travel within such a limited context would have been unrealistic and would not provide meaningful insights for local policy intervention or organizational measures.

Therefore, the procedure mirrors the one previously outlined, but with the adjusted distance ranges and assumptions. This allows the study to highlight the impacts that are locally relevant, offering a more targeted perspective on the role of transport in the overall environmental footprint within the Cuneo area.

Table 4.4: Transport emissions by distance and mode of travel

Distance range	Total attendees	Avg. distance (km)	Bike	Car	Van/Camper	Bus	Train	Emissions ($kgCO_2e$)
0–50 km	2,858	16.73	39.2%	59.5%	0.0%	0.0%	1.4%	**6,475**
50–75 km	294	59.05	0.0%	84.6%	0.0%	11.5%	3.8%	**3,735**
Beyond 75 km	1,805	75.00	0.0%	84.6%	0.0%	11.5%	3.8%	**28,022**
Emission factors ($kgCO_2$/pkm)			0	0.112	0.107	0.102	0.017	
Emissions ($kgCO_2e$)			–	**34,243**	**3,664**	**132**	**193**	**38,232**

Table 4.4 reports the environmental impact of transportation under the defined geographical boundary. Out of a total of 38.23 tonnes of CO_2e, cars alone account for 34.24 tonnes, by far the largest contributor, as well as the most widely used means of transport among event attendees. Other modes of transport, with the exception of bike (which has no direct emissions), represent a marginal share.

Given this context, the scenario analysis focuses on car travel. The emission factor adopted in this study represents an average value, reflecting different car sizes and fuel types. A detailed breakdown (e.g., distinguishing between petrol, diesel, hybrid, or electric cars) would have required a more in-depth survey with specific questions, increasing the complexity and potentially reducing the reliability of the responses. Similarly, while technological improvements would naturally reduce emissions, this aspect lies outside the scope of the present study, which instead considers the emission factor for the car as an average and independent value.

A parameter that, instead, can be directly influenced within the local context is the *vehicle occupancy rate* (VO). Based on survey data, the average VO was estimated at 1.73 passengers per car. As previously discussed, the vehicle occupancy is a key variable in modeling travel impacts and identifying strategies to reduce emissions. A scenario analysis was conducted assuming a 20% increase in VO, achievable for example through car-sharing initiatives. This change alone would reduce transport-related emissions by approximately 15%, lowering the total environmental impact of transport to 32.52 tonnes of CO_2e, as shown in Table 4.5.

Table 4.5: Comparison of scenarios

	Base Scenario	**Optimized Scenario***
Car occupancy rate (people/vehicle)	1.73	2.08
Emission factor ($kgCO_2e$/pkm)	0.112	0.093
Total emissions ($kgCO_2e$)	38,232	32,525
Emissions reduction	**15%**	

*Assuming an increase of 20% in car occupancy.

Such an increase is not only plausible but also actionable, as the event organizers could implement measures to encourage car pooling. Jones, in his book on sustainable event management, suggests practical solutions such as offering incentives (e.g., free parking, vouchers, on-site discounts, or rewards) for fully occupied cars, or applying disincentives such as a “green tax” for under-occupied vehicles [30].

In summary, several strategies could be considered by the organizers to mitigate transport emissions within the Cuneo boundary:

- Promoting bike use for local participants and visitors.
- Encouraging greater use of public transport, such as trains and buses, which were only marginally used.
- Increasing vehicle occupancy rates, especially for cars, through incentives and public engagement initiatives.
- Introducing dedicated shuttle services designed specifically for the event, departing from major towns in the province or nearby municipalities, to collect participants and visitors and bring them directly to the event area.

4.2.2 Accommodation

As outlined in the participant and visitor profile analysis, although the highest attendance was recorded on race day - the last of the three days - the presence of side events and dedicated exhibitor areas throughout the weekend, and, above all, the high level of international participation, meant that a significant share of participants and visitors stayed more than just one day within the Cuneo area, inside the defined geographical boundary. Given the substantial travel distances for many attendees, accommodation was identified as a key category to include in the environmental impact assessment as highlighted in previous studies [13, 17, 42].

The impact of accommodation was evaluated by combining survey data with estimated environmental impacts of accommodation facilities drawn from comparable studies. Participants and visitors were classified by both their origin and their chosen type of accommodation, as presented in Table 4.6. Based on the average length of stay of each group (Table 4.2), the total number of overnight stays was estimated and distributed across different accommodation categories.

Table 4.6 reports the distribution among the main accommodation types. Commuters refer to participants who did not stay overnight but stayed at home; unsurprisingly, this category accounts for 88% of local participants. Hosted for free indicates those accommodated without charge by friends or relatives, while the Bed & Breakfast (B&B) category also includes rented apartments. As expected, commuters represent a small share among national participants and are absent among international ones, while B&Bs and hotels remain the most common choices for those who stayed overnight.

Table 4.6: Accommodation types by distance distribution

	Commuters	Hotel	B&B	Camping	Hosted for free
Local	88.0%	5.0%	4.0%	2.0%	1.0%
National	16.3%	44.9%	26.5%	4.1%	8.2%
International	0.0%	40.7%	44.4%	11.1%	3.7%

It should be noted that the accommodation emissions for participants who stayed in their own homes or were hosted for free are excluded from the analysis. This simplification was primarily made due to the difficulty of obtaining reliable data on household consumption, and attempting to estimate it would have introduced additional uncertainty into the study. Moreover, participants staying in their own homes would have consumed energy and resources regardless of the event, so their presence does not constitute a direct incremental impact on the local community. This assumption is further reinforced when considering the economic impact analysis presented in the next section. In that context, only participants who actually spend money on accommodation - such as those staying in hotels, B&Bs, or campsites - are accounted for.

To estimate accommodation-related emissions, values from the recent study by Wang on a sporting event in China [54] were used. That study provides consumption data in terms of electricity, fuel for hot water, waste, and food for different types of hotels. For the analysis of Granfondo La Fausto Coppi, only medium hotels and B&Bs were considered, with the consumption data summarized in Table 4.7.

In this category, only the consumption of those staying in hotels and B&Bs/ apartments was considered. Regarding camping, consumption could be estimated as 1 kWh of electricity per person per night, plus use of sanitary facilities and waste generation, resulting in approximately 0.5 kg of CO_2e per person per night. Due to the lack of reliable data and the limited relevance (only 349 overnight stays in camping were recorded), the emissions from camping were considered negligible compared to the total impacts and not fundamentally relevant given the broad scope of the study; therefore, they were not included in the final results.

Operational consumptions were assigned emission factors using Ecoinvent LCI data [16] for waste-to-landfill, waste transport, water, and natural gas, while electricity emissions were calculated using ISPRA data [28]. To estimate breakfast-related emissions, a standard breakfast was assumed, and emissions were calculated using Agribalyse 3.2 [1]; the list of ingredients and their corresponding emission factors is provided in Appendix B.3. Finally, the total emissions per person per

Table 4.7: Summary of accommodation-related data [54]

Types of Hotel	Parameter Value (per Night and per Person)
Medium hotel	Electricity: 20 kWh Fuel for hot water: 7 MJ Water: 300 L Waste (municipal waste): 1 kg Breakfast: 1 standard breakfast
Bed and Breakfast (B&B)	Electricity: 10 kWh Fuel for hot water: 3.5 MJ Water: 150 L Waste (municipal waste): 0.5 kg Breakfast: 1 standard breakfast

night were multiplied by the number of overnight stays in each accommodation type, with the results presented in Table 4.8. In addition, the analysis accounted for the accommodation of exhibitors, officials, staff members, and media representatives such as journalists, totaling 50 individuals, each staying for two nights (three days), resulting in an additional 100 overnight stays for the hotel category.

Table 4.8: Accommodation emissions summary

	Hotel	**B&B**
Emission factor kgCO_2eq/person-night	7.41	4.23
Overnight stays person-night	1,889	1,460
Emissions kgCO_2eq	14,000	6,179
% of total	69.38	30.62
Total emissions: 20,179 kgCO_2eq		

The values 7.41 and 4.23 here reported refer to kg CO_2e per person per night. In the scientific literature, it is often expressed per night per room, which would require assumptions about the number of occupants per room (typically two). The results obtained in this analysis fall within the range of values reported per room when assuming two people per room and can therefore be considered reliable. For instance, Piccerillo reports a value of 14.3 kg of CO_2e per room assuming two occupants[42], which is comparable to the value obtained in this study.

The analysis of the accommodation category shows a total of 20.18 tonnes of CO_2e across 3,697 overnight stays (including camping overnight stays), as reported in Table 4.8. Approximately 70% of these emissions are generated by hotel stays, due both to higher per-night consumption compared to B&Bs and to a larger number of hotel overnight stays.

As with travel, reducing accommodation-related emissions is challenging since they both fall within *Scope 3 emissions*. However, the type of accommodation chosen by attendees can significantly influence the overall impact. Given the uncertainty in the consumption data - which comes from a context different from that of this event - and following the methodological approach outlined at the start of this section, a best scenario was modeled by assuming a 20% reduction in per-night consumption for both hotels and B&Bs, as presented in Table 4.9.

Table 4.9: Best scenario: 20% reduction in consumption

Reduced consumption (20% reduction)			
Parameter	**Unit**	**Hotel**	**B&B**
Electricity	kWh	16	8
Natural gas	MJ	5.6	2.8
Water	L	240	120
Municipal waste	kg	0.8	0.4
Waste transport	tkm	0.024	0.016
Breakfast	item	1	1
Emission calculations			
Emission factor	KgCO_2eq/person-night	5.97	3.42
Overnight stays	person-night	1,889	1,460
Emissions	kgCO_2eq	11,270	4,997
Total emissions: 16,267 kgCO_2eq			

This assumption is supported by the fact that in events where sustainability is a key theme, local accommodation providers - particularly those located in and around the race area - are likely to adopt more resource-efficient and waste-reducing practices, either as a result of targeted awareness campaigns or to align with the event's sustainability values. Such behavioral changes could realistically result in lower electricity, water, and waste-related emissions.

Moreover, incorporating this reduction allows for a simple sensitivity analysis that illustrates how targeted improvement actions in accommodation management could represent an effective emissions-reduction strategy. Under this best-case scenario, total accommodation-related emissions would decrease to 16.27 tonnes of CO_2e, showing a 19% reduction compared to the baseline scenario.

4.2.3 Food and Beverage

The environmental impact assessment of the Food & Beverage category focused exclusively on two areas directly managed by the organizers: the approximately 1,600 post-race meals distributed to participants and the six feed zones located along the course, where food and beverages were offered during the race. During cycling events, riders receive food and drinks at designated areas along the route, commonly referred to as feed zones (*stazioni di ristoro*). In this study, the term feed zones will be used consistently to indicate these points, which provide refreshments to participants. Consumption by visitors or by participants outside the official organization (such as meals in bars and restaurants) was deliberately excluded, as including these contributions would have introduced an extremely high degree of uncertainty, requiring arbitrary assumptions on average per-capita consumption and greatly increasing the complexity of both data collection and interpretation, while at the same time providing results of limited reliability and relevance. Restricting the analysis to food and drinks officially provided by the organizers made it possible to focus only on areas under their direct control, thus evaluating the tangible effect of concrete choices such as the type of food served, the sourcing of ingredients, the packaging materials, and the management of organic waste.

The quantification of impacts followed a Life Cycle Assessment approach in line with ISO standards, using the Agribalyse 3.2 database[1], which provides cradle-to-grave emission factors for a wide range of food products. These values are expressed as $\frac{\text{kg CO}_2\text{e}}{\text{kg product}}$ and are broken down into stages such as production, transformation, packaging, transport, distribution, and consumption. The Life Cycle Inventory was built using primary data collected directly from the event organizers: in particular, the staff member responsible for Food & Beverage provided the complete list of recipes, ingredients, quantities, the number of meals actually served in the 2024 edition, as well as details on the types of materials used (e.g. trays, cups, biodegradable cutlery). For the feed zones, it was assumed - based on the organizers' feedback - that approximately 70% of the available food was actually consumed, with the remainder considered as waste. Where necessary, assumptions were made regarding the inclusion of ingredients, excluding those contributing less than a tablespoon per recipe, as their contribution to total emissions was considered negligible. For transparency, when specific foods were not available in the database, reasonably similar items were used as substitutes to approximate their impact.

The actual meals provided by the organizers included a biodegradable tray containing pasta with tomato sauce and cheese, meat (braised beef), fruit, dessert, and water, as shown in Table 4.10. All the components - including water - were provided by local sponsors, meaning that nearly all the food could be considered locally sourced or *zero-kilometer*, which further emphasizes the relevance of assessing the impact of sourcing and logistics.

In practical terms, the environmental assessment of the Food & Beverage category consisted of compiling the full inventory of food items and beverages, calculating the total quantity of each product expressed in kilograms, and applying the corresponding emission factor from Agribalyse 3.2 [1]. The total impact was then obtained by summing the contribution of each food item. All details of the inventory, recipes, ingredient lists, and emission factors are reported in Appendix B.4, while in this section only the total emissions and the reductions obtained in the best-case scenario are presented.

Materials

Food & Beverage category also includes the emissions associated with the materials used for serving meals and at the feed zones, such as cups, plates, and cutlery, as well as the organic waste generated per meal. When data for these materials were not available in Agribalyse, scientific studies were used. From the information provided by the event organizers, it was known that, in addition to the careful sourcing of food from local suppliers, all tableware used for meal distribution was biodegradable and compostable. The tableware was made from bio-based materials including Mater-Bi, biodegradable and bioplastic material made from starch and other bio-based components, and polylactide (PLA), a compostable plastic derived from renewable resources such as corn starch, as well as paperboard and paper.

A challenge for the analysis was that it is often difficult to find data directly from the manufacturers, and many studies only compare conventional plastic materials without specifying quantities and emissions. Consequently, this analysis of materials heavily relies on the study by Fieschi and Pretato, "Role of compostable tableware in food service and waste management: a life cycle assessment study"[20] as well as the Environmental Product Declaration (EPD) by Novamont for Mater-Bi [39]. In their study, Fieschi and Pretato conducted an LCA comparing two food service systems in quick-service restaurants or catering, including two different waste treatment scenarios, creating a "best-case" and "worst-case" framework similar to the approach outlined in previous sections. Scenario A (best case) used biodegradable and compostable tableware, particularly PLA and Mater-Bi, with all waste collected as a single homogeneous stream and sent to organic recycling through composting. Scenario B (worst case) used traditional single-use plastic tableware, with all waste collected as a heterogeneous stream and disposed of via incineration and landfilling. Their functional unit was the supply of 1,000 meals using 1,000 single-use tableware items, generating 150 kg of food waste (0.150 kg/meal) and tableware waste. The mass and composition of each tableware component are detailed in Appendix B.4. Fieschi and Pretato [20] found that the best-case scenario produced 109 kg of CO_2e, while the worst-case scenario produced 221 kg of CO_2e, showing a 51% reduction when using biodegradable and compostable tableware combined with organic recycling. This confirmed that using compostable tableware with proper waste management is the preferred option for catering, as it significantly reduces carbon, water, and resource footprints and aligns with circular economy principles.

To apply their results to the event under study, all material quantities were scaled to the 1,600 meals provided during the Granfondo La Fausto Coppi event, adapting the CO_2e emissions to the functional unit specified in Chapter 3. For cups used in the feed zones, the Novamont 2011 EPD for Mater-Bi [39] was used. This approach allowed the analysis to accurately quantify the environmental footprint of tableware and food waste while relying on robust, literature-based LCA data and adjusting it to the specific context of the event.

Table 4.10: Food and Beverage emissions

Meals	**Worst scenario ($kgCO_2e$)**	**Best scenario ($kgCO_2e$)**	**Reduction (%)**
Tomato Pasta	530.8	456.0	14.1
Braised Beef	2,890.7	2,656.6	8.1
Water bottle, fruit and dessert	437.3	227.9	47.9
Tableware and organic waste	353.6	174.4	50.7
Feed zones	1,163.6	795.1	31.7
Total emissions	5,376.0	4,310.1	19.8

Table 4.10 presents the CO_2e emissions for the Food and Beverage category, showing the contribution of each meal provided at the event. To identify a "best scenario," which reflects the actual practice of the organizers as one of their main sustainable initiatives, it was assumed that, since all food is supplied locally from producers and suppliers in the Cuneo area, the emissions associated with transportation could be considered negligible. This approach allows the analysis to highlight the potential reduction in emissions achieved by sourcing meals entirely locally.

This assumption is acknowledged as strong, as the underlying data are drawn from databases from a different context (mainly French), and detailed information on the original data sources is limited. However, the objective of the analysis, as in all environmental impact categories, is to illustrate areas of potential improvement and to demonstrate when these improvements can translate into tangible results. By assuming zero emissions from food transport, the analysis reveals an overall reduction of 19.8%, showing how the organizers' commitment to sustainable practices - such as local sourcing and the use of biodegradable tableware - can have a measurable effect on the overall environmental footprint.

In addition, this scenario also entails social benefits: sourcing meals entirely locally increases visibility for local producers, strengthens engagement with the local community, and allows the event to promote information about the origin of the products being served. This approach not only reduces environmental impact but it also enhances the social connection between the event and the local area.

The result can be summarized as follows:

- Conservative scenario (worst): meals sourced from non-local suppliers and use of single-use plastic products.

$$\text{Total emissions} = 5.38 \text{ tonnes } CO_2e$$

- Best scenario: meals sourced from local suppliers (km zero) and use of single-use biodegradable products.

$$\text{Total emissions} = 4.31 \text{ tonnes } CO_2e$$

4.2.4 Energy Consumption

This analysis focuses on the energy consumed during the three days of Granfondo La Fausto Coppi 2024 and its associated environmental impact. The primary output is the estimation of avoided emissions, made possible by the sustainable choices implemented by the event's organizers and calculated using emission factors from the Italian Institute for Environmental Protection and Research (ISPRA)[28].

Electricity for the event was supplied by eVISO [19] and monitored through five separate electricity meters. The consumption metered was *7,673 kWh*. This energy consumption accounted for different activities including stage lighting and sound systems, temporary event structures, large video screens, the tent area, food and beverage stands, and exhibitor stands in the central square.

From a greenhouse gas accounting perspective, the electricity consumption falls under Scope 2 emissions - indirect emissions from purchased electricity. Scope 2 emissions are produced at the facilities of the electricity provider and are expressed in CO_2e. Two main calculation methods are commonly used to calculate these emissions:

- Location-based represents the average carbon intensity of the national electricity grid, independent of the electricity supplier. For Italy in 2023, ISPRA reports an average grid emission factor of 0.2572 kg of CO_2e per kWh [28].

- Market-based approach accounts for the emissions associated with the electricity actually purchased by the organization, taking into account contractual instruments such as renewable energy certificates or Guarantees of Origin (GO).

Applying the location-based factor to the event's consumption results in an estimated impact of 1,969 kg of CO_2e, as shown in Equation 4.3.

$$\text{Scope 2 Emissions} = 7{,}673\ \text{kWh} \times 0.2572\ \frac{\text{kg CO}_2\text{e}}{\text{kWh}} = 1{,}969\ \text{kg CO}_2\text{e} \tag{4.3}$$

However, the organizers have a formal supply contract with eVISO [19] for *100% renewable energy*, certified through Guarantees of Origin (GO). This ensures that an amount of renewable electricity equivalent to the event's consumption is fed into the grid, effectively bringing the market-based emission factor close to zero. As a result, the event avoided nearly two tonnes of CO_2e emissions compared to a scenario using standard grid electricity.

It is important to note that, while electricity delivered to end customers will physically be an aggregate of all sources on the grid, green contracts play a central role in supporting renewable generation. Through the acquisition of certified renewable supply, the organizers contribute directly to the transition towards a lower-carbon energy system and reflect their environmental responsibility in event management.

4.2.5 Waste Management

The final category of environmental analysis concerns waste management. Although this category generally represents a relatively small share of environmental and economic impacts in the context of sport events, it remains relevant from a sustainability perspective due to the visibility of waste practices and their potential educational value for participants and visitors. This relevance is further reinforced by the initiatives undertaken by the event organization to promote waste reduction and proper sorting.

As in other sections of this study, the lack of direct measurements presented a significant challenge. Primary data collection for waste generation is notoriously difficult in public events, especially without dedicated on-site audits. Nevertheless, to provide a quantitative estimate and maintain comparability with other categories, it was considered important to develop a simplified methodology that could produce a reasonable approximation of CO_2e emissions from waste management. It is therefore important to recognize that the estimates presented here are subject to considerable uncertainty and should be interpreted as indicative values within the broader context of the study.

To ensure methodological consistency, waste from accommodation and food and beverage (i.e., the post-race meal for participants) is excluded from this category, as it has already been accounted for in their respective sections. The waste management category therefore only takes account of waste generated on site during the three days of the event by participants, visitors, and staff. This covers all waste streams going to landfill, compost, and recycling, including both transportation to the end-of-life facility and the treatment phase.

Given the absence of direct measurements, the total amount of waste generated was estimated based on scientific literature and information obtained from interviews with the staff member responsible for waste management during the event. The most relevant reference was the case study by Dolf [13] on the Special Olympic Games (SOC 2014) in Canada, which shares similar system boundaries and methodological assumptions. In that study - where accommodation and food-related waste were also excluded - data collected through on-site waste audits indicated an average of 0.9 kg of waste per person per day, resulting from systematic observations of bin fill percentages for each waste stream, totaling 22 tonnes of waste generated for that event under study. This finding, grounded in empirical fieldwork, was deemed the most appropriate benchmark for this study.

$$\text{Waste generated} = 0.9\ \frac{\text{kg}}{\text{person} \cdot \text{day}} \times 7{,}138\ \text{person} \cdot \text{day} = 6{,}424\ \text{kg} \tag{4.4}$$

Equation 4.4 estimates the total waste generated during the event by multiplying the average waste generation rate per person per day by the total number of person-days over the three-day period (as calculated earlier in this chapter). Based on this approach, the Granfondo La Fausto Coppi was estimated to have generated a total of 6.42 tonnes of waste.

The estimated total waste generation for this case study was then broken down by waste type. Since no direct composition analysis was available, an indirect approach was applied: the number, capacity (in liters), and location of waste bins were obtained from the waste management coordinator. By multiplying the total volume available for each waste type by average density values [44], it was possible to approximate the capacity in mass per each waste type, based on the number of bins available. These values were then expressed as a percentage of the total estimated waste capacity, producing a composition breakdown that was cross-checked for plausibility against typical waste profiles for similar events.

Using the total waste generated shown in Equation 4.4, and multiplying it by the percentage share of each waste type, it was possible to estimate the amount of waste generated for each category.

Table 4.11 presents the indirect method used to obtain the approximate waste composition breakdown by mass.

Table 4.11: Approximate waste composition breakdown

Waste Type	Large Bins (660L)	Small Bins (240L)	Total Vol. (m^3)	Avg. Dens. (kg/m^3)	Total Capacity (kg)	% of Total	Estimated Waste (kg)
Municipal waste	14	0	9.24	180	1,663	36%	2,336
Plastic	12	3	8.64	75	648	14%	910
Glass/Cans	2	0	1.32	280	369	8%	519
Paper	15	3	10.62	90	955	21%	1,342
Compost	0	13	3.12	300	936	20%	1,315
Total	43	19	–	–	4,572	100%	6,424

For waste management, five types of bins were available: mixed waste (municipal waste), organic waste, plastic, paper, and glass/metal. The table also reports the number of containers available for each waste type.

It should be noted that the bins were strategically placed in critical areas along the meeting and starting zones of the event, ensuring that they were both easily available and accessible. In addition, each bin was accompanied by clear signage, following a consistent colour scheme across the event venues, in order to encourage proper waste sorting.

Finally, for each waste type, the estimated mass was multiplied by the respective emission factor to obtain the total CO_2e emissions for the waste management category.

Impacts include both the transport to end-of-life and the end-of-life treatment. Life Cycle Inventory (LCI) data were sourced from the Ecoinvent 3.9.1 database [16], and the IPCC 2013 GWP 100a method was applied for the Life Cycle Impact Assessment (LCIA). All modeling was conducted using OpenLCA. For waste transport, a one-way distance of 20 km to the landfill or recycling plant was assumed to be performed by a lorry (21 tonnes). All the emission factors are provided in Appendix B.5.

As with all other categories, both a worst-case and a best-case scenario were modeled due to the inherent data uncertainty and the aim of providing sensitivity to the analysis, highlighting potential areas for improvement.

- Worst-case scenario: composting of organic waste, with all remaining waste sent to sanitary landfill (high-impact assumption).

- Best-case scenario: composting of organic waste, incineration of municipal waste (without energy recovery credits), and recycling of paper, plastic, and glass (no credits applied).

For the recycling scenario described in the best case, a cut-off no-benefit approach was applied, as outlined by Dolf [13]. Under this method, the event - as waste producer - receives no credits for the potential environmental benefits of recycled materials. Only the direct impacts of waste management are taken into account, including collection, transport, and sorting of waste. This conservative approach avoids double counting (i.e., assigning credits both to the waste producer and the recycler) and recognizes that not all waste sent to recycling is actually recycled, due to quality issues or technical limitations.

Table 4.12: Waste Management Emissions Comparison

Worst Case Scenario		
Waste Type	**Waste Generated (kg)**	**Emissions (kg CO_2e)**
Municipal waste	2336.7	1395.5
Plastic	910.4	115.8
Glass/Cans	519.3	19.2
Paper	1342.8	322.5
Compost	1315.0	143.7
Total	**6424.1**	**1996.7**
Best Case Scenario		
Waste Type	**Waste Generated (kg)**	**Emissions (kg CO_2e)**
Municipal waste	2336.7	825.3
Plastic	910.4	23.9
Glass/Cans	519.3	13.6
Paper	1342.8	35.2
Compost	1315.0	143.7
Total	**6424.1**	**1041.7**

Table 4.12 shows the comparison of emissions between the best and worst-case scenarios. Results indicate that, in the worst-case scenario, waste sent to landfill dominates the overall impacts across all waste categories. Summarizing:

- Worst-case scenario: 1.99 tonnes CO_2e - composting of organic waste, with all remaining waste sent to landfill.
- Best-case scenario: 1.04 tonnes CO_2e - composting of organic waste, incineration of municipal waste, and recycling of paper, plastic, and glass under the cut-off approach (no credits applied).

While assigning environmental credits could have had a significant impact on the best-case scenario, the purpose of this study is to show that even when focusing solely on waste management, effective waste sorting and minimizing landfill disposal can significantly cut down CO_2e emissions. In this case study, proper sorting and treatment of waste can lead to nearly a 50% reduction in emissions, clearly demonstrating the tangible benefits of better waste management practices.

4.2.6 Summary of Environmental Impact

Given the length of the results analysis, and considering that the environmental impact assessment requires collecting and processing numerous data for each category, this section provides a concise summary. The aim is to offer a clear overview of the findings, allowing the contributions of different areas to be combined and discussed in the following chapter, as well as to support the overall multi-dimensional analysis.

For each category, both a worst and a best scenario were considered to show the potential effects of sustainable practices. In some areas, such as energy consumption or food and beverage, the best scenario reflects the strategies that the event organizers have already implemented. In other cases, the optimized scenario was developed in contrast to a more conservative one, allowing to provide sensitivity to the outcomes under the inherent data uncertainty. The assumptions adopted to build this scenario were based on reasonable motivations and grounded in well-justified reasoning.

Table 4.13: Environmental Impact Results

Category	Worst scenario (kg CO_2e)	Best scenario (kg CO_2e)	Reduction	% of Total
Transport	38,232	32,525	14.9%	56.43%
Accommodation	20,180	16,267	19.4%	29.78%
Energy Consumption	1,969	–	100.0%	2.91%
Food and Beverage	5,376	4,310	19.8%	7.93%
Waste Management	1,997	1,042	47.8%	2.95%
Total	67,753	54,144	20.1%	

Regarding CO_2-equivalent emissions, the total estimate is 67.75 tonnes of CO_2e for the worst case scenario and 54.14 tonnes of CO_2e for the best case scenario, indicating a potential reduction of 20.1% (Table 4.13). All emissions are generated within the province of Cuneo, with transport and accommodation clearly dominating, together accounting for over 85% of total emissions. This result is totally consistent with findings from other studies on sports events (Chapter 2).

To provide a meaningful result that can also be comparable with similar events, emissions per participant were calculated by dividing total emissions by the estimated 7,138 attendances throughout the event. This results in 7.58 kg CO_2e per participant in the best case scenario and 9.49 kg CO_2e in the worst case scenario, defining a range of potential emissions per participant.

Finally, Figure 4.3 clearly shows that transport and accommodation are the two categories with the highest environmental impact. The visual comparison between best and worst scenarios also highlights how adopting sustainable practices and improvement strategies produce tangible effects across all five areas analyzed, confirming the effectiveness and the potential of the organizers' sustainability strategies.

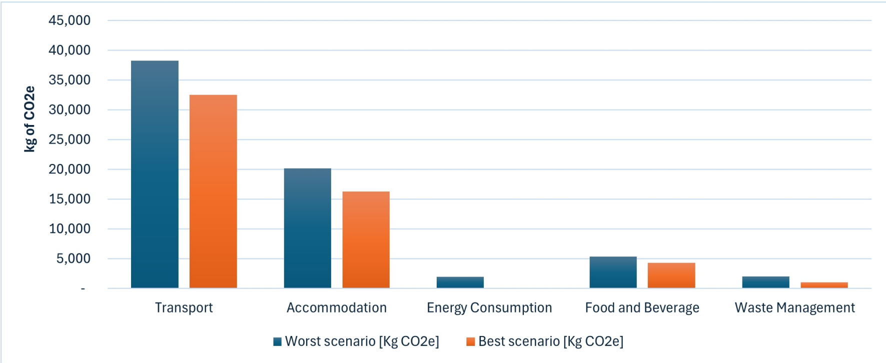

Figure 4.3: Summary of Environmental Impact

4.3 Economic Impact

As described in Chapter 2, the economic impact assessment in this study is framed within the LCSA (Life Cycle Sustainability Assessment) framework through the application of Life Cycle Costing (LCC). Unlike the environmental dimension, where the LCA methodology is well-established and dominant, the economic assessment allows for greater flexibility: different approaches exist and may vary significantly in structure and scope.

In line with the LCSA framework, this study follows the same goal and scope definition used for the environmental assessment (see Chapter 3). This approach ensures methodological consistency across the three dimensions of sustainability, with a shared goal, intended application, audience, functional unit, and system boundaries. However, the key distinction lies in the product system being analyzed. While the environmental impact was broken down into specific areas of analysis (Figure 3.2), the economic assessment focuses on the direct and indirect expenditures sustained by the main stakeholders involved in the event: participants, visitors, and organizers.

In practice, this section proceeds as follows: firstly, direct costs sustained by each stakeholder are estimated through primary data generated from the survey; secondly, they are aggregated to obtain the overall direct impact and finally, appropriate multipliers are applied to account for indirect and induced effects in line with established literature on economic impact assessment, yielding the overall economic impact on the local territory.

This approach reflects a multi-stakeholder perspective, aligning with the LCSA principles, which emphasize the analysis of different categories of impact and multiple actors within the system. Here, the “system” refers to the local area of Cuneo, defined by specific geographic and temporal boundaries. The assessment is therefore carried out from the perspective of this local territory. Following the logic of Life Cycle Costing, the analysis considers these flows as costs, namely the economic resources spent within the local community to enable and sustain the event. The expenditures by participants, visitors, and organizers thus reflect the contributions of different stakeholders that, once combined, define the economic impact on the territory. In conclusion, the economic impact analysis aims to capture the total spending generated within the host territory, accounting not only for the direct costs incurred locally but also for the indirect and induced effects that these expenditures trigger in the broader economy. This approach offers a comprehensive picture of the event's economic contribution to the local community, while maintaining coherence with the LCSA framework applied throughout this study.

4.3.1 Expenditure by participants and visitors

The objective of this section is to estimate the average daily expenditures, as well as the total expenditures over the three days of the event, for both participants and visitors. Accounting for the spending behavior of attendees is essential to accurately capture the initial economic stimulus generated by the event.

The estimation is based on the results of the participant survey. To improve the quality of the analysis and provide better insights, reported expenses were categorized into specific spending areas, and respondents were also segmented according to their place of origin. In line with previous phases of the study, three origin groups were considered - local, national, and international - and it was assumed that the survey sample reflects the broader participant population. The analysis focuses specifically on the 2024 edition of the event, as its distribution of attendees most closely matched the survey sample.

In addition, in line with the assumptions already adopted for the environmental assessment (for example, in the case of accommodation), visitors are assumed to exhibit the same daily spending patterns as participants. Although this is a strong assumption, it was the only feasible approach to include visitors in the analysis and to ensure consistency across dimensions. Consequently, average daily expenditures were derived from the survey responses, differentiated by category of origin, and then applied to the number of participants and to the estimated number of visitors reported in Table 4.1.

To construct the spending profiles of attendees, three categories of expenditures were considered, excluding accommodation (which is analyzed separately in the following section): food and beverage, shopping (including purchases at exhibitor stands and local businesses) and extra events and services (such as museums or related cultural activities). While the Table 4.14 summarizes only the total daily expenditure, a detailed breakdown by spending categories is reported in Appendix B.6.

To obtain total expenditures, the analysis also incorporates the average length of stay, previously reported in Table 4.2. Since this was expressed in nights, it was converted into approximate numbers of days: one day for local participants, two days for national participants, and four days for international participants. The same values were applied to visitors under the assumption of similar behavior. The procedure can be summarized as follows:

$$\text{Total Spending} = \sum_{c \in \{loc,nat,int\}} N_c \cdot D_c \cdot S_c \tag{4.5}$$

Where N_c is the number of participants and visitors belonging to the category c; D_c are the daily stays and S_c the average daily expenditure.

Table 4.14: Total expenditure by participants and visitors

	Avg. daily expenditure [€]	**Participants**	**Visitors**	**Length of stay [days]**	**Total expenditure [€]**
Local	39.89	1,351	2,108	1	137,956
National	67.89	602	381	2	133,458
International	77.42	347	193	4	167,166
				Total	**438,580**

The results reported in Table 4.14 illustrate the distribution of daily spending among event attendees, segmented by distance of origin. The analysis highlights how international participants recorded the highest average daily per capita expenditure (€77.42), significantly higher than that of local participants (€39.89). This outcome reflects expected behavioral differences: local attendees tend to spend less, as they often bring their own food and rarely dine at restaurants or engage in additional shopping or leisure activities. By contrast, national and international attendees - although fewer in absolute numbers - contribute substantially to overall expenditure.

In particular, the higher length of stay of international attendees amplifies their impact, as they are more inclined to dine out, shop locally, and participate in cultural or recreational activities.

The overall average daily expenditure per attendee amounts to €61.73, but this value really depends on where the participants are originating from. This Figure was also compared to the *Piedmont European Region of Sport 2022* report [14], which estimated an average daily spending of €80 per person across twelve major international sport events held in the region. The lower value of 61.73€ in this case study is therefore consistent, considering that the analyzed event had a different scale and participant profiles. Additionally, the comparison suggests that the estimates presented here adopt a more cautious approach, aiming to provide an objective picture of the event's economic impact rather than inflating numbers through overly optimistic spending assumptions.

Finally, an additional expenditure category was included to account for staff, officials, volunteers, exhibitors, and media representatives. In this case, the average daily spending was estimated through informal interviews with the organizers, assuming a uniform value for all individuals in this group. Considering their average length of stay, the total expenditure for this category was estimated at €6,543. The total expenditure by visitors and participants, including staff and officials, is:

$$\textbf{Total Expenditure by attendees} = 438{,}580\ € + 6{,}543\ € = \textbf{445,123 €} \quad (4.6)$$

4.3.2 Accommodation Expenditure

The analysis of accommodation expenditure was carried out in parallel with the environmental assessment of the same category. In this case, instead of emission factors, average prices were assigned to the number of overnight stays for each accommodation type. The detailed procedure is described in the first part of this chapter (accommodation section), to which reference can be made for methodological consistency.

Table 4.15: Expenditure by accommodation types

Accommodation types	**Cost per person per night [€]**	**Overnight stays**	**Total expenditure [€]**
Hotel	85	1,889	160,524
B&B	60	1,460	87,571
Camping	18	349	6,287
		Total	**254,384**

Table 4.15 reports the number of overnight stays per accommodation type - including participants, visitors, staff, and officials - together with the assigned average price per person per night.

Price estimates were derived from major hotel online travel agencies (OTAs) and further validated through discussions with local stakeholders. Given that accommodation facilities in the municipality of Cuneo are nearly fully booked during the event period, actual prices could be higher. However, in line with the conservative approach of this study, average values were applied. This assumption is also supported by the *Osservatorio Turistico del Cuneese* report , which indicates that OTA-reported prices for Cuneo range between €88 and €100 per night [40].

The total estimated spending on accommodation amounts to €254,384, with hotels accounting for more than 60% of that amount. This is largely due to their higher average prices and the greater number of overnight stays compared to other categories. As expected, international participants provide the largest contribution to this category, thanks to their longer length of stay. Conversely, local attendees contribute minimally, as most of them do not require overnight accommodation.

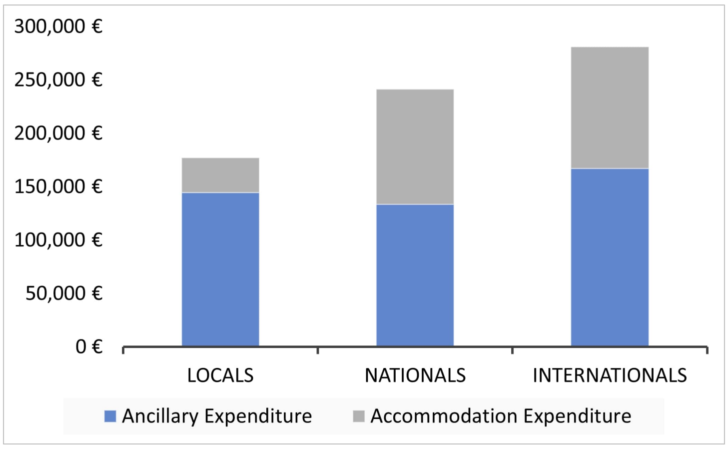

Figure 4.4: Summary of expenditure by event attendees

Figure 4.4 summarizes the breakdown of expenditures by participant origin and category of expenses: ancillary expenditure includes the expenses made by participants and visitors in the three categories previously described. The histogram clearly shows a gradual increase in spending as the distance of origin grows.

4.3.3 Organization Expenditure

The last category of direct expenditure to be considered in the economic impact assessment concerns the costs borne by the organizers for the management of the event. To determine these expenditures, detailed information on the type and origin of the expense was required. For this purpose, the event manager provided a breakdown of the expenses sustained for the 2024 edition, which were subsequently aggregated into four macro-categories and represented in the pie chart of Figure 4.5.

The total organizational expenditure for the 2024 edition of the *Granfondo La Fausto Coppi* amounts to:

$$\textbf{Total organization expenditure} = \textbf{184,000 €} \tag{4.7}$$

The expenditures have been grouped into the following four categories:

- Administrative and operational costs: office rent, electricity, consumables, insurance, administrative fees, and taxes.
- Communication, promotion and representation: advertising, marketing, hospitality, and representation expenses.
- Event and activity organization: equipment rental, competition fees, officials, sports material, prizes, staff reimbursements, and transportation.
- Social and special projects: health and medical services, community-oriented initiatives.

It is important to note that expenditures by sponsors were not included within these categories, as they represent revenues for the organizing body. Since such funds are already allocated to cover organizational expenses, including them would result in double counting.

Figure 4.5: Breakdown of Organization Expenditure

Figure 4.5 clearly shows that *event and activity organization* represents the largest share of expenditure. This category includes equipment rental (such as exhibition stands and stage), reimbursements for staff and collaborators, and all expenses directly related to the race itself, such as judges, timing services, and competition management. The second largest category is *administrative and operational costs*, which covers bureaucratic and management expenses, followed by *communication and marketing*. Finally, *social and special projects* category accounts for a smaller share of expenditure.

A meaningful comparison can be drawn with the *Piemonte European Region of Sport 2022* report, which provides benchmark values of organizational spending across different types of events. According to the report, the average cost for 12 major events held in Piemonte in 2022 was €523,162 per event, whereas the average cost for events organized by Sports Federations was €61,062 per event [14].

The total organizational expenditure for the Granfondo La Fausto Coppi, which stands at €184,000, lies exactly in the middle of these two benchmarks. This placement truly captures the nature of the event: while it cannot be classified as a large-scale event, it also goes far beyond a standard federation-level sport event. Its international character, a variety of side activities, and its deep symbolic and historical significance for the local community, make it a unique medium-scale event with an identity of its own.

The value of €184,000 therefore underlines both the commitment and the efficiency of the organizing staff in running the event year by year. It shows that, despite operating at a fraction of the average cost of major events, the organization manages to maintain high-quality standards capable of ensuring strong attendees' satisfaction, while avoiding unnecessary expenditure.

4.3.4 Total economic impact

Once the total direct expenditure was obtained by summing the spending of participants, visitors, and organizers, it was possible to measure the immediate effect of the event, namely the inflow of new financial resources into the host territory that would not have occurred without the event. This direct impact represents the first layer of the economic assessment and serves as the basis for calculating the total economic impact, as it is shown in Table 4.16.

The total direct impact amounts to:

$$\textbf{Direct Impact} = 444{,}123 \text{ €} + 254{,}384 \text{ €} + 184{,}000 \text{ €} = \textbf{883,508 €} \tag{4.8}$$

To estimate the overall effect - including direct, indirect, and induced impacts (discussed in Chapter 2) - the analysis relies on Input-Output (I/O) models, originally developed by Wassily Leontief [34]. These models capture the interdependencies between sectors within a given economy, illustrating how spending in one sector generates further demand across others. The resulting multipliers summarize the magnitude of these secondary effects, translating initial expenditures into broader economic outcomes for the territory. In this way, the analysis moves beyond a simple measure of direct spending to capture the virtuous cycle of economic activity triggered by the event.

The study applied two different multipliers: one for the expenditures of participants and visitors, and one for the organization expenditure. These multipliers were derived from the study of the *93° Fiera Internazionale del Tartufo Bianco d'Alba*[41], an event held annually in the Province of Cuneo, the same territorial context as the present case study. In that report, the multipliers were constructed through a localized input-output matrix: starting from national supply and use tables published by ISTAT [29], the data were downscaled to the provincial level, aggregating national branches into 28 local sectors. Location quotients were then applied to regionalize the coefficients, ensuring that the interdependencies among industries accurately reflected the local economic structure. The resulting multipliers for participants and visitors expenditure and organizational expenditure came out as 2.12 and 1.91, respectively, and these values capture the direct, indirect, and induced effects of expenditures within the provincial economy.

Since the spending profiles and economic sectors involved in the Granfondo La Fausto Coppi are of the same kind as those for the truffle fair, and since both events are situated within the same provincial context, it was deemed appropriate to adopt these multipliers for the present study. This choice also aligns with values reported in other studies on sports events. For example, the report *Piemonte European Region of Sport 2022* [14] applied an overall multiplier of 2.11, which is almost the same value here adopted. Such consistency establishes the robustness of the approach while avoiding the significant complexity and specialized expertise that would have been required to recalculate multipliers independently.

Table 4.16: Summary of economic impact

Category of Expense	**Amount**
Ancillary expenses	445,123 €
Accommodation	254,384 €
Organization	184,000 €
Direct Impact	**883,508 €**
Organization multiplier	1.91
Expenses multiplier	2.12
Total Impact	**1,834,396 €**

Table 4.16 summarizes the results of the economic impact assessment, showing the breakdown of expenditures that contributed to the total impact. Ancillary

expenses - including participants' and visitors' spending on food and beverage, shopping, and extra services - emerge as the largest contributors. A key point of interest is the role of multipliers in amplifying the overall effect: ancillary expenses and accommodation costs were adjusted using a multiplier of 2.12, in practice more than doubling their direct value, while organizational expenditures were multiplied by 1.91. Through this process, the direct impact of €883,508 expands to a total economic impact of €1,834,396. This significantly higher amount accounts not only the direct flows of expenditure but also the indirect and induced effects captured through the input–output framework, providing a comprehensive estimate of the event's economic contribution to the local community.

4.4 Social Impact

Finally, this section addresses the third dimension of the Triple Bottom Line (TBL). After analyzing the environmental and economic impacts, the Results chapter concludes with the assessment of the social impact, thus providing a comprehensive evaluation of the Granfondo La Fausto Coppi's sustainability performance across all three TBL dimensions. The social dimension of the Life Cycle Sustainability Assessment was addressed through an adapted Social Life Cycle Assessment (S-LCA) framework, guided by the principles of ISO 14075:2024 [6] but applied in an innovative way to the context of a cycling event. Given the recent publication of the standard and the absence of established applications for sport events to assess social impact using this methodology, the approach is deliberately exploratory and intended to test how S-LCA can be operationalized in this context.

The analysis focused on two main stakeholder groups: the participants, who are the primary beneficiaries of the event, and the local community, which experiences the broader social and cultural effects. For the participants, a set of quantitative indicators was created, including a socio-demographic breakdown (age, gender, nationality), a return rate indicator (which tracks the share of participants attending previous editions), and satisfaction levels measured through a Likert-scale survey. For the local community, qualitative insights were gathered on inclusivity and community engagement, highlighting how the event involves volunteers, local businesses, and residents.

The choice of these indicators reflects a strong effort to obtain measurable and comparable data, enabling results that not only describe the social footprint of this edition but also provide a framework that can be replicated in future editions and potentially adapted to other events, which was one of the main objectives of this research. In this way, the methodology moves beyond communicative evidence and aims to establish a consistent, semi-quantitative basis for assessing social performance.

This application demonstrates that, even in a service-oriented setting such as a small to medium sized event, the S-LCA perspective can offer valuable insights. By combining data from participants with reflections on community, the study provides a structured way for capturing positive social outcomes, identify areas for improvement, and enhancing to the overall sustainability profile of the event.

4.4.1 Socio-demographic analysis

This section builds on the data already presented in Table 3.1, which reported the age, gender, and distance distribution of the participants in the 2024 edition. Using the registration records, a brief overview of the demographic composition of participants is provided here.

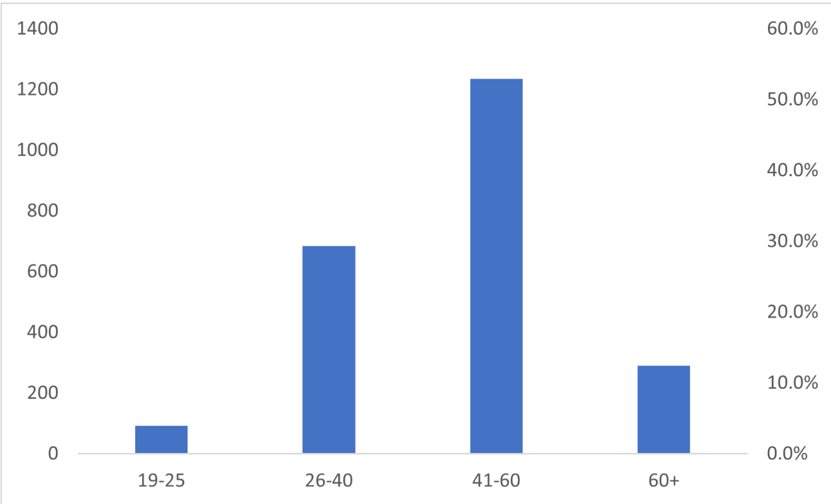

Figure 4.6: Age distribution for 2024 edition

Figure 4.6 illustrates the age distribution of the 2,300 participants through a histogram. The majority of attendees fall within the 41–60 age group, which alone represents 53.7% of the total. This is followed by the 26–40 category, accounting for approximately 30%, while older participants (60+) make up 12.6% of the total, corresponding to 290 individuals. Finally, the youngest group (19–25) accounts for only 4% of the participants.

Although relatively straightforward, this analysis highlights how the primary interest in amateur cycling events of this type is concentrated among adults in the 41-60 age range, reflecting both the behavioral patterns and economic profiles typically associated with this segment of participants.

Table 4.17: Nationality breakdown by edition

Edition 2024	
Nationality	**% of total**
Italy	81.09
France	4.00
Netherlands	3.87
Rest of the World	11.04
Countries represented	**36**

Edition 2023	
Nationality	**% of total**
Italy	84.60
France	6.54
Netherlands	2.18
Rest of the World	6.68
Countries represented	**25**

Edition 2021	
Nationality	**% of total**
Italy	83.04
France	6.34
Netherlands	4.83
Rest of the World	5.79
Countries represented	**22**

Edition 2019	
Nationality	**% of total**
Italy	82.55
France	5.95
Netherlands	4.06
Rest of the World	7.44
Countries represented	**38**

Looking at the breakdown of participants' countries of origin shown in Table 4.17, more than 80% of attendees across all the last four editions were Italian, confirming the strong domestic base on which the event relies.

Nevertheless, a significant share of participants consistently came from abroad, with France and the Netherlands emerging as the two most represented foreign countries after Italy. This trend has remained stable across the four editions analyzed, with Italy, France, and the Netherlands always occupying the top three positions. What stands out about the 2024 edition is not just the increased number of international participants but also the greater diversification of their origins. The "rest of the world" category accounted for 11.04% of the total participants - exceeding both France at 4% and the Netherlands at 3.97%. This shows that, beyond the usual foreign markets, the event is increasingly attracting riders from a broader variety of countries, such as Guatemala, New Zealand, Australia, and Brazil.

Overall, the 2024 edition recorded participants from 36 different nations, an increase compared to 25 in 2023 and 22 in 2021, though slightly below the peak of 38 registered in 2019. Across the last four editions, the Granfondo La Fausto Coppi has hosted cyclists from a total of 53 different countries, underlining its growing international appeal and ability to attract participants well beyond national borders.

4.4.2 Return rate

The return rate indicator measures the event's ability both to attract new participants and to build loyalty among those who have already experienced previous editions. In this sense, it provides insight into the event's appeal as well as its capacity to create a strong attachment among returning participants. Beyond its interpretative value, the indicator is also useful for benchmarking across different editions of the same event, identifying trends, or comparing events of different scales.

To obtain this indicator for the Granfondo La Fausto Coppi, registration files from the four most recent editions (2024, 2023, 2021, and 2019) were closely analyzed. These spreadsheets included personal information such as date of birth, gender, and city of residence, excluding the participants' names. Consequently, an identification procedure was implemented: if a participant across two different editions had the same date of birth, gender, and municipality of origin, it was assumed to be the same individual. This method inevitably carries a slight chance of error - for instance, in cases of incorrect data entry or changes in residence - but given the size of around 2,300 participants in each edition, any potential bias is minimal and does not compromise the validity of the percentage-based indicator.

Applying this procedure to the 2024 edition, it was found that out of 2,300 participants, 1,224 had already taken part in at least one of the three previous editions, corresponding to a return rate of 53%, as shown in Table 4.18. Within this group, 713 participants had competed in at least two editions, while 16% of the total participants had been present in all three previous editions. These results highlight both a strong loyalty rate - since more than half the population of participants returned - and the continued attractiveness of the event, with 47% of participants not present in the previous edition. In other words, the event demonstrates the ability to combine participant retention with the capacity to attract new attendees year after year.

Table 4.18: Return rate for 2024 edition

Editions participated*	**Participants**	**Italians**	**Foreign**	**Return rate****
At least one edition	1224	90%	10%	**53%**
At least two editions	713	93%	7%	**31%**
All three previous editions	357	92%	8%	**16%**

*Edition participated before the 2024 edition

**Return rate calculated on the total of 2,300 participants of 2024 edition.

It is also worth noting that the majority of returning participants were Italians, accounting for nearly 90% of returning attendees. This outcome was expected, as many locals - the most populated group - face limited travel distances and are therefore more likely to return, although a small share of foreign participants also proved to be attracted by the event. To further validate these findings, results were cross-checked with the responses to the "social section" of the survey, where participants were asked whether they had taken part in previous editions. That analysis revealed a return rate of 52% between the 2023 and 2024 editions, calculated on the 176 survey respondents. This value is extremely close to the 53% obtained from registration files (Table 4.18), reinforcing the reliability of the result.

4.4.3 Participants' Satisfaction

To complement the analysis of the social impact on participants, the survey also investigated their experience in previous editions of the event, focusing on overall satisfaction. As shown in Figure 4.7, 176 respondents evaluated their experience across five categories: overall organization, services and logistics, safety and road signs, atmosphere and engagement, and cleanliness and waste management. The evaluation was carried out using a 5-point Likert scale, where 1 corresponded to "very dissatisfied" and 5 to "very satisfied." In this way, the survey allowed an assessment of the perceived social dimension of the event, essentially capturing its "customer satisfaction" from the participants' perspective.

Figure 4.7: Participants' Satisfaction level (average data; n=176)

The results show an average satisfaction score of 4.13 out of 5 (indicated by the orange line in Figure 4.7), reflecting a generally very positive perception of the event. Among the different categories, participants expressed the highest appreciation for the overall organization and for atmosphere and engagement, highlighting both the effective management of the event and the sense of inclusion created around it. The remaining three categories - services and logistics, safety, and waste management - also received consistently high evaluations, averaging around 4 out of 5.

4.4.4 Community engagement and inclusivity practices

This conclusive section of the social impact assessment and Results chapter provides a qualitative discussion focusing on the second main stakeholder group considered: the local community. Beyond the economic effects already analyzed in the previous section - such as the benefits for local businesses and the broader financial flows into the territory of Cuneo - this analysis highlights initiatives and practices implemented by the organizers to foster inclusivity and strengthen the event's relevance for the community.

First, the event provides significant visibility to local associations and businesses, giving them the opportunity to showcase their work at exhibition stands in the expo area. Particularly iconic is the Nations' parade (*Sfilata delle Nazioni*), which takes place the afternoon before the race. During this parade, the flags from all the represented countries are carried in procession to the main square of Cuneo, highlighting both international appeal and community involvement.

A wide range of collateral events, largely organized by local associations, further expands the social dimension of the Granfondo La Fausto Coppi. These include non-competitive rides such as a city ride designed for children aged 6–12, playful cycling activities supervised by qualified instructors, road safety education, guided walks, and even a half-marathon. Such activities demonstrate how the event extends beyond the competitive race, engaging diverse groups of the community and encouraging widespread participation. Importantly, most sponsors and partners involved are local, which further amplifies the event's role in supporting the surrounding territory.

At the same time, the organizers emphasize the international character of the event by partnering with tour operators who offer complete travel packages for participants coming from abroad. In the most recent 2025 edition, the presence of the Argentine ambassador throughout the event days exemplified the effort to build transnational connections, as the organization is actively collaborating on projects to promote similar cycling events in Argentina. These partnerships highlight not only cultural and social ties but also potential economic synergies for the host territory.

Finally, inclusivity is further reflected in the composition of the organizing staff, which relies on a large number of volunteers. Among them there are volunteers with disabilities, engaged in logistical, hospitality, and support roles. This initiative, developed in collaboration with local associations, goes beyond symbolic inclusion by ensuring the active and meaningful participation of people with disabilities in the delivery of the event.

Chapter 5

Discussion

This dissertation analyzed a single case study applying the Life Cycle Sustainability Assessment (LCSA) framework to a small to medium sized sport event held in Cuneo, Italy. The research pursued a twofold objective. First, it aimed to evaluate the sustainability performance of the event, identifying areas of improvement and providing insights for organizers and stakeholders. In this respect, the analysis highlights how the event affects the local community and how sustainable practices - whether already implemented or reasonably assumed - can deliver tangible results, particularly in the environmental dimension, but also with significant social and economic implications. Second, the study sought to propose an integrated and replicable methodology for the comprehensive assessment of small to medium sized events, in line with ISO standards and the LCSA framework. The approach is designed to share a common goal and scope definition, functional unit, and system boundaries across all three dimensions of sustainability, while remaining adaptable to their specific analytical requirements. With due attention, this framework can be replicated in subsequent editions of the same event or adapted to different contexts, sizes, and typologies of events.

The chapter begins by presenting and interpreting the results outlined in Chapter 4. The initial section takes a closer look at the outcomes across the three dimensions - environmental, economic, and social - highlighting impact patterns and main findings. The aim here is to offer a clear and logical interpretation of these results, while also reflecting on methodological choices and the overall analytical framework.

The second section attempts to provide a holistic evaluation of sustainability performance, integrating the three dimensions into a broader perspective. Given the intrinsic difficulty of combining heterogeneous indicators, the discussion relies on internally developed benchmarks in order to evaluate the event's performance and identify areas for potential enhancement.

Finally, the chapter broadens the perspective by outlining a general framework for applying the proposed methodology to other sport events, providing guidance on how the LCSA approach can be adapted across different scales and contexts. This section also highlights the main limitations and critical aspects of this approach, while identifying opportunities for methodological improvement. In addition, it revisits the research objectives introduced in Chapter 1, assessing the extent to which they were achieved and proposing directions for future research aimed at consolidating and expanding the role of LCSA in the sustainability assessment of sport events.

5.1 Results Overview and Key Findings

The case study analyzed in this dissertation is the Granfondo La Fausto Coppi, a cycling event held annually in Cuneo, Italy. The Granfondo has consolidated a strong reputation both nationally and internationally within the amateur cycling sector, attracting around 2,300 participants every year from across the world, while simultaneously representing a major occasion for the local community by engaging stakeholders, associations, and local businesses.

The 2024 edition, which serves as the basis for this study, recorded a total of 2,300 registered participants. Consistent with previous editions, the majority (54%) fell within the 41–60 age group, highlighting the strong appeal this type of event has among middle-aged cyclists. Following them were participants aged 26–40. In terms of distance of origin, approximately 59% (1,351 participants) were locals, living within 100 km from Cuneo. Meanwhile, 26% (602) were nationals (100–600 km), and 15% (347) were internationals (over 600 km). This breakdown was essential for the impact analysis that followed, as the distance of origin was closely linked to variations in environmental footprint, spending patterns, and visitor behavior.

Survey data also provided insights into the number of visitors accompanying participants. Locals reported the highest average ratio, with 1.56 visitors per participant, compared to 0.63 for nationals and 0.56 for internationals. These results reflect the higher likelihood for local athletes to be joined by friends and family, given the short travel distance. By combining visitor estimates with permanence data, the study calculated a total of 7,138 attendances across the three days of the event—highlighting the capacity of the event to significantly increase the flow of people in the host city and to generate a tangible impact on the local area.

Environmental Impact

The environmental impact assessment of the Granfondo La Fausto Coppi offers valuable insights and directions for organizers seeking to evaluate and reduce the carbon footprint of small to medium scale international sport events. As expected, travel of participants and visitors emerged as the dominant contributor, accounting for 56.43% of total CO_2e emissions within the defined geographic boundary (75 km from Cuneo). If long-distance travel, including international flights, had been fully included, transport alone would have amounted to 531.8 tonnes of CO_2e, largely driven by long-haul flights from participants coming from more than 2,000 km. For this reason, the study applied a regional boundary to better highlight the tangible effects of strategies that can realistically be implemented by the organizers.

Within transport, two major factors were particularly decisive: travel distance and vehicle occupancy rate. A sensitivity analysis revealed that a 20% increase in car occupancy rate could reduce transport emissions by about 15%. This suggests actionable strategies such as promoting carpooling through incentives (e.g., discounts for vehicles with two or more passengers, or higher fees for single-occupant cars), alongside awareness campaigns. Other planning measures, such as encouraging the use of trains, buses, or bikes for shorter trips, or even providing shuttle services from nearby towns, could further reduce emissions.

Beyond mobility, additional measures could address other impact areas. The use of locally sourced food, partnerships with accommodation facilities to improve efficiency and reduce consumption, renewable energy procurement through Guarantees of Origin (GO), and waste management practices represent feasible impact reduction strategies. In the best scenario modeled, which combined several of these strategies, total emissions dropped from 67.75 tonnes CO_2e to 54.14 tonnes CO_2e, a reduction of almost 20% compared to the baseline.

To contextualize these findings, the study compared its results with Dolf's environmental assessment of the Special Olympic Games in Canada (SOC 2014)[13]. When expressed per attendee, the case study here analyzed showed a footprint between 7.58 kg CO_2e (best scenario) and 9.49 kg CO_2e (worst scenario), based on 7,138 estimated attendances. For comparison, Dolf's assessment of SOC 2014 originally reported aggregate emissions, but by adapting his results to the same regional boundary applied in this study - considering emissions of transport within the regional area - and given the overlap in methodological approach and categories of analysis, the estimated footprint corresponds to 10.75 kg CO_2e per person. While the two events differ in scale, location, and participant profiles, the similarity in magnitude confirms the robustness of the present assessment. Moreover, the Granfondo's best-case outcome demonstrates a comparatively lower impact per attendee, highlighting both the effectiveness of sustainable practices already in place and the potential of further strategies to enhance performance.

Finally, the environmental analysis of the Granfondo La Fausto Coppi not only identifies targeted actions for reducing emissions but also positions the event within a broader benchmarking exercise, showing encouraging results when compared with similar studies. This dual outcome - both diagnostic and comparative -

provides event organizers with a concrete foundation for future decision-making and continuous improvement.

Economic and Social Impact

The assessment of the economic and social dimensions required a methodological adaptation to ensure coherence with the overall LCSA framework while remaining applicable to the specific features of a sport event. Both dimensions were approached with reference to standardized methodologies, such as Life Cycle Costing (LCC) for the economic pillar and Social Life Cycle Assessment (S-LCA) for the social one, but their implementation necessarily differed from conventional product-oriented applications. Rather than analyzing a product system divided into process-based areas, as was done for the environmental assessment, these dimensions adopted a stakeholder-centered perspective, reflecting the fact that events are service-oriented systems whose impacts are mediated through people and communities.

In the case of the economic impact, the analysis was conducted from the perspective of the host territory, treating the local economy as the “system” under study. Expenditures made by participants, visitors, and organizers were measured and then expanded through multipliers to estimate the total effect, capturing not only direct but also indirect and induced impacts.

For the social dimension, the methodology was inspired by the multi-stakeholder logic of S-LCA but adapted to the characteristics of an event. The assessment focused on two main groups: participants, whose perceptions, satisfaction, and return rate were analyzed through survey data; and the local community, for which a qualitative discussion was carried out at the end of Chapter 4, highlighting inclusivity practices, side events, and cultural initiatives connected to the event. The aim was not to achieve a fully standardized measurement but to generate comparable and replicable indicators, offering a semi-quantitative framework for evaluating social performance.

The assessment of the total economic impact, which also included indirect and induced effects obtained through multipliers, resulted in €1.83 million, against €883,508 of direct expenditures. Within this total, expenses of participants and visitors emerged as the main contributors. These results are illustrated in Table 5.1 and compared with those estimated for the 2025 edition of the Granfondo La Fausto Coppi.

A key point in interpreting these results lies in the structure of the methodology. Since expenditure estimates were based on survey-derived parameters such as average spending per participant category (local, national, international), number of visitors per participant, average length of stay, and accommodation choices, the overall impact is linearly related to the number and distribution of participants. In other words, once spending behaviors and organizational costs are held constant, the only variables driving the outcome are the size and composition of the participant base.

Table 5.1: Ecomonic Impact of the 2024 and 2025 editions

Item	**Edition 2024**	**Edition 2025**	**Variation**
Spending categories			
Participants & visitors spending	445,123 €	470,279 €	+5.3%
Accommodation expenditure	254,384 €	270,007 €	+5.8%
Organization expenditure	184,000 €	193,000 €	+4.7%
Direct impact	**883,508 €**	**933,286 €**	
Organization multiplier	1.91	1.91	
Spending multiplier	2.12	2.12	
Total impact	**1,834,396 €**	**1,938,037 €**	**+5.3%**
Participants and retention			
Total participants	2,300	2,530	
Return rate	53%	56%*	
Geographical distribution			
Local (<100 km)	1,351 (59%)	1,467 (58%)	
National (100–600 km)	602 (26%)	762 (30%)	
International (>600 km)	347 (15%)	301 (12%)	
Estimated overnight stays	3,697	3,895	
Estimated total presences	7,138	7,812	

* Return rate calculated over the period 2019–2025, including the 2024 edition.

To illustrate this point, the methodology was applied to the 2025 edition, assuming that the participants' spending patterns, visitor ratios, and accommodation choices remained the same as in 2024 edition. The only adjustments concerned the total number of participants - 2,530 instead of 2,300 - and their distribution among distance of origin categories. This straightforward replication resulted in an estimated total economic impact of €1.93 million, which is roughly 5% higher than in 2024. Interestingly, this increase occurred even though there was a slight reduction in the share of international participants, who typically spend more and stay longer. The growth in overall participant numbers was the key driver behind this rise.

This exercise highlights the strength of the adopted framework: its relative simplicity and adaptability make it accessible even to non-experts, such as event organizers, who may wish to estimate economic impacts across different editions.

While the method relies on assumptions and inevitably introduces approximations - since data are drawn from a single survey and extrapolated to other editions - it provides a practical and communicable estimate, particularly valuable for marketing, stakeholder engagement, and media visibility. More detailed analyses would require fresh primary data collection, yet the approach as applied here strikes a useful balance between robustness and usability.

Table 5.1 also provides the return rate indicator, which is a key measure of how well the event attracts new participants and, at the same time, fosters loyalty among those who have attended the previous editions. For 2025, the return rate increased from 53% to 56%, partly due to the longer reference period considered (2019–2025 instead of 2019–2024). This indicator is straightforward to interpret and highly relevant for event organizers. A very low return rate would suggest that the event is effective at attracting new participants but struggles to retain them, while a very high value would indicate strong loyalty but limited capacity to engage new participants. With a value slightly above 50%, the Granfondo La Fausto Coppi appears to strike a balanced position, combining loyalty within its participant base with continued attractiveness for newcomers. This interpretation is further supported by the high levels of participant satisfaction recorded in the survey (average 4.13 out of 5 across five categories, with atmosphere and organization rated highest). Maintaining this balance in return rate should be a target for future editions, ideally standardizing the time span for return rate calculations (e.g., consistently using the last five editions) to ensure comparability.

Another important social dimension is the event's internationalization. The 2024 edition counted participants from 36 different countries, and 53 have been represented across the last four editions. This international profile is not only symbolically reinforced through initiatives such as the parade held the evening before the race, but also carries significant implications for the host community. The presence of international participants enhances the event's economic impact, as confirmed by the expenditure analysis, while also strengthening its social and cultural relevance. For instance, the presence of the Argentine ambassador during the event highlights opportunities for building diplomatic and economic ties beyond the purely sporting dimension.

In terms of local engagement, the event relies heavily on community involvement, with volunteers and local associations supporting both the main race and side events across the three days. These collateral activities further increase the social inclusion and relevance of the event for the host territory.

Looking at the whole picture, these results underscore the importance of small to medium scale events for local communities. Beyond their economic impact, they act as powerful tools for social inclusion, cultural exchange, and territorial promotion. In line with the growing global attention to sustainability - expressed across environmental, social, and economic dimensions as also outlined by the SDGs - the event industry increasingly positions itself as a vehicle for sustainable practices and community development. Through the inflow of visitors and participants, these events generate tangible revenues and visibility for the host territory, while also serving as models for sustainable practices such as local food sourcing, waste reduction, and low-carbon emissions mobility strategies. In this sense, events like the Granfondo La Fausto Coppi illustrate how sport events can serve as instruments to encourage sustainability, while gradually setting higher standards of efficiency and social responsibility in event management.

5.2 Comprehensive Sustainability Performance

Integrating the three sustainability dimensions into a single performance evaluation is a recognized challenge in the literature, as the economic, environmental, and social pillars are measured with different units and cannot be directly aggregated. As Valdivia notes, "the formal equation LCSA = LCA + LCC + S-LCA cannot be taken literally" [51]. Moreover, Kloepffer claims that a formal weighting across pillars shall not be performed, since it would allow trade-offs that misrepresent the balance among dimensions [32]. Therefore, in the LCSA evaluation phase, it is generally recommended that there is no weighting between the three pillars. The three evaluations are considered equally relevant, and a worse "performance" of one pillar cannot be compensated by a better "performance" of another. Likewise, monetizing all impacts in a single currency, while theoretically possible, is both ethically and methodologically problematic - particularly for social and environmental impacts - and risks double counting.

To overcome these issues, this study adopted a composite index approach, where indicators were normalized and aggregated. Specifically, results were showed through a radar chart, inspired by the approach of Wang et al. [55], which is widely used in sustainability reporting for its intuitive layout. Each axis on the chart represents one of the three pillars, scaled from 0 to 100, where 100 corresponds to a strategic target representing the “ideal” or best achievable performance. The actual performance of the event was plotted against this benchmark, creating a triangular shape that immediately highlights strengths and weaknesses across pillars, as illustrated in Figure 5.1.

In this case, the ideal benchmark was not derived from external studies, since comparability across events is limited due to methodological differences, but was instead defined internally in collaboration with the organizers. This allowed the target scenario to reflect the long-term strategic objectives of the event and ensured that the evaluation remained directly relevant to decision-making. The radar chart thus provides both a graphical snapshot of performance and a basis for deriving an integrated score measuring the sustainability.

The main strength of this approach is its communicative clarity and its ability to guide planning . By visualizing how far each dimension is from its ideal target, organizers can identify where to focus their efforts - whether that's minimizing environmental impacts within the geographical boundaries, increasing local economic activities, or enhancing social engagement.

The integrated score evaluation does not claim to be a comprehensive measure of sustainability performance, but rather a tool to support awareness and facilitate decision-making for future editions, by highlighting the areas for improvement.

In order to make the indicators more meaningful, less misleading, and easier to interpret, a normalization procedure was applied. Specifically, for each sustainability dimension, two reference points were defined: a minimum value ($x_{\min}$), representing the lower bound of acceptable performance and assigned a score of 0, and a target value ($x_{\max}$), representing the desired goal and assigned a score of 100. The actual score to measure the performance of the 2024 edition was then rescaled within this interval using the following formula:

$$\text{Score} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \times 100 \tag{5.1}$$

This transformation ensures that all indicators across the three dimensions are expressed on a common 0–100 scale. In this way, the obtained score reflects the value achieved compared to the defined target, while also providing a clear indication of the distance from the minimum acceptable performance and the potential for improvement.

The introduction of a minimum reference value is particularly relevant to avoid skewed interpretations. For instance, in the economic dimension, it would be unrealistic to assign a score of zero to an economic impact equal to €0, since an event inevitably generates at least some level of spending. In this case study, the research assumed a minimum bound of €1,000,000 for an event of such size. Normalizing between two meaningful benchmarks, rather than from zero to the maximum, therefore ensures a more realistic and interpretable evaluation.

The normalized scores for each impact dimension and for each individual indicator are presented in Table 5.2, together with the corresponding minimum, target, and achieved values for the 2024 edition.

	Minimum	**2024 Edition**	**Target**	**Score**
Economic Impact [mln €]	1	1.83	2.2	**69.17**

Social Impact	**Minimum**	**2024 Edition**	**Target**	**Score**
Return Rate	0.35	0.53	0.60	72
Satisfaction level	1	4.13	5	78.25
Nations represented	15	36	40	84
				78.08

Environmental Impact [kg CO_2eq. per person]	**Minimum**	**2024 Edition**	**Target**	**Score**
Transport	10.58	5.36	4.56	86.71
Accommodation	3.84	2.83	2.28	64.74
Energy Consumption	0.28	0	0	100.00
Food and Beverage	0.75	0.6	0.6	100.00
Waste Management	0.28	0.15	0	46.43
				79.58

Table 5.2: Economic, Social and Environmental performance scores.

For the economic impact, the target of €2.2 million was set in agreement with the organizers, who are confident that, given the steady growth of the event and its ability to attract more participants, local businesses, and communities - as already shown by the increase between the 2024 and 2025 editions in Table 5.1 - this goal can be achieved within the next three to four years. The resulting score of 69.17 out of 100 shows clear room for improvement. Progress in this area is expected to come primarily from increasing participant spending, particularly on extra activities and services, which currently represent the lowest spending category. Extending the average length of stay, fostering stronger connections with local associations and businesses to promote more side-events, and modestly expanding the investment by the organizational committee would also contribute to achieving the economic target.

With regard to the environmental dimension, absolute values of CO_2e emissions are not particularly informative, as they scale directly with the number of participants. To provide a fairer evaluation, impacts were expressed on a per-person basis across the five categories analyzed, considering the 7,138 estimated attendances. Minimum, target, and actual values were defined based on the scenario analysis presented in Chapter 4. Here, obviously, the logic is reverse, as lower values, expressed in CO_2e per person, correspond to better performance. For example, in the transport category, the minimum value corresponded to a conservative scenario where all participants traveled alone by car (Vehicle Occupancy (VO) equal to 1) within the defined geographical boundary, while the 2024 edition value and the target value were taken as the conservative and optimized scenario (which assumed a 20% increase in car occupancy rate) previously discussed in Chapter 4. A similar procedure was applied to the other categories of analysis, allowing impacts to be rescaled and compared on a per-capita basis. This resulted in an average score of 79.6 out of 100 for the environmental pillar.

Overall, this relatively high score indicates that there is limited room for improvement in this area. Most of the emissions fall under Scope 3 type, where the organizing committee has only indirect control — through measures such as incentives or awareness campaigns. For this reason, the environmental target was defined largely with reference to the best-case scenario already modeled in Chapter 4, representing a realistic yet ambitious benchmark for organizers to aim at in future editions.

Finally, the social dimension was evaluated by using three quantitative indicators presented in Table 5.2, resulting in a score of 78.08 out of 100.

The three overall scores obtained are visualized in the radar chart shown in Figure 5.1, where the triangular shape of the actual performance is compared against the ideal reference triangle. This representation provides an immediate overview of strengths and weaknesses across the pillars and clearly highlights which areas require further effort to move closer to the defined targets.

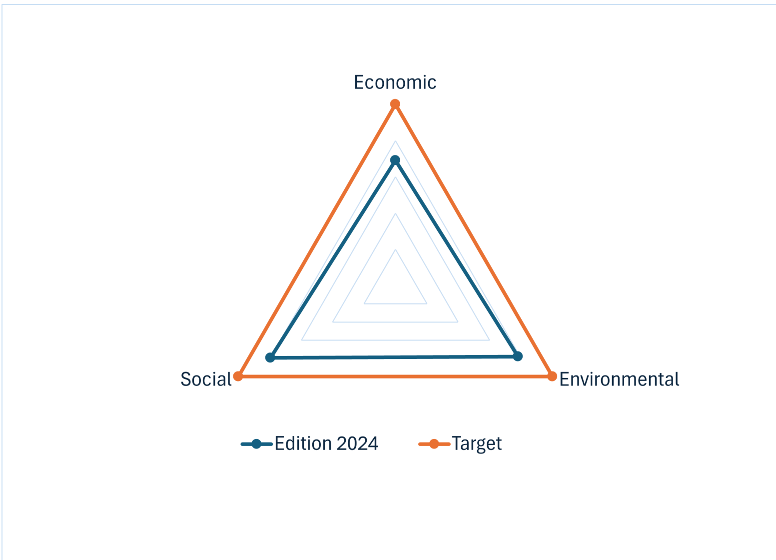

Figure 5.1: Radar representation of the sustainability performance across economic, environmental, and social dimensions, in comparison with the ideal scenario

To synthesize the results into a single sustainability performance score, the study applied the distance-to-ideal method, a simplified adaptation of the TOPSIS framework where the three dimensions were equally weighted, using the formula presented in Equation 5.2.

$$S_{\mathrm{sus}} = 100 \left(1 - \frac{\sqrt{(100 - s_{\mathrm{eco}})^2 + (100 - s_{\mathrm{env}})^2 + (100 - s_{\mathrm{soc}})^2}}{100\sqrt{3}} \right) \tag{5.2}$$

The resulting composite indicator, S_{sus}, provides an integrated evaluation of overall performance relative to the strategic benchmarks. For the 2024 edition, the value obtained was $S_{sus} = 75.17$. This result indicates a solid level of sustainability performance for a medium-sized event that is actively seeking to improve.

However, it is important to emphasize that this value is not intended as an absolute measure nor as a basis for external comparison. Since the benchmarks are internally defined in accordance with the organizers, the score should be regarded as an internal control tool, useful for guiding decision-making and tracking progress across successive editions. Declaring transparent strategic objectives - although arbitrary - is far preferable to comparing against non-homogeneous numbers derived from different contexts or methodologies. In this sense, the framework proves its adaptability and relevance: it enables continuous monitoring of progress while providing organizers with practical insights into which sustainability dimensions are closer to the target and which require additional effort.

5.3 General Framework and Limitations

This final section revisits the research objectives outlined in Chapter 1, with the aim of assessing whether they were met and of translating the analytical process into a generalizable framework. As anticipated, the dissertation had a twofold objective. The first was to assess the sustainability performance of the Granfondo La Fausto Coppi, thereby providing event organizers and stakeholders with insights for communication, awareness, and decision-making. This goal has been achieved by identifying key contributors, highlighting areas of improvement, and proposing strategies to enhance sustainability. Moreover, an integrated view across the three pillars — environmental, economic, and social — was developed to evaluate the overall performance of the event, according to the Triple Bottom Line approach.

On the other hand, the research had another significant objective: to propose a methodology that could be easily adapted and reused for other editions of the event or even for various events of different sizes and contexts. The present study doesn't claim to have established a standardized or definitive method; instead, it offers a structured and replicable framework inspired by the Life Cycle Sustainability

Assessment (LCSA) approach, adapted to the specific context of sport events. While LCSA is typically applied to product systems, this research showed how its principles - such as life cycle thinking, integration of the three sustainability pillars, and considering stakeholders' perspective - can be effectively transferred to the service-oriented and temporally bounded system of an event.

For this reason, Figure 5.2 outlines the general framework derived from the analysis carried out in this dissertation. It summarizes the key phases that guided the study - goal and scope definition, system boundary setting, data collection, impact assessment across each dimension, and interpretation of results. These phases are not meant to replace the established LCSA methodology but to reinterpret it in the context of event assessment, leaving room for adaptation to different settings. In this way, the dissertation proposes an integrated framework that can be refined, replicated, and further developed for the sustainability assessment of other events.

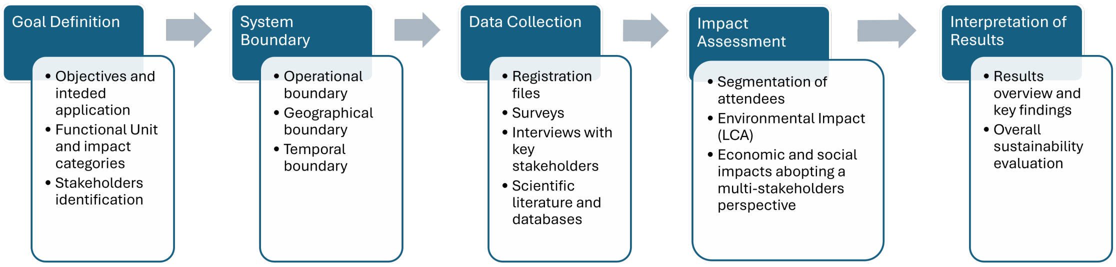

Figure 5.2: Proposed framework for the sustainability assessment of events, highlighting the five analytical phases in line with the LCSA methodology

- *Phase 1 – Goal Definition*: The first step in any sustainability assessment is the clear definition of the study's goals. This involves identifying the intended audience, the purpose of the analysis, and the intended application of the results. Depending on whether the focus is on communicating results to the general public, providing data for decision-making, or supporting long-term strategy, the functional unit and scope of the study must be adapted accordingly. For instance, the analysis may cover the overall sustainability profile of a single event, allow comparisons between multiple editions, or concentrate on specific phases of the event life cycle such as planning, execution, or closure. At this stage, it is also crucial to identify the main stakeholders involved. For sport events, these typically include participants, visitors, organizers, local suppliers, sponsors, and the host community. Each group has its own role in shaping the event's impacts, and their inclusion ensures that the analysis captures a realistic and multi-stakeholder perspective of sustainability. Equally important is the early selection of impact categories and indicators that will guide the study. These choices determine the data requirements and influence the type of results that can be obtained, highlighting the strong interdependence between the goal definition and the subsequent phases of the analysis.

- *Phase 2 – System Boundary Definition*: Once the objectives are defined, the boundaries of the system under study must be established. This is arguably the most critical phase, as the definition of temporal, geographical, and operational boundaries ensures consistency throughout the analysis. Boundaries impose necessary constraints: they determine which processes, activities, and flows are included, and which are excluded.

  For events, boundaries may be defined temporally, geographically (e.g., a radius around the host city), and operationally (e.g., categories such as transport, accommodation, energy, food, or waste). The choice of boundaries strongly affects both the difficulty of data collection and the relevance for the interpretation of results. A clear and balanced definition is therefore essential. In this case study, the adoption of a 75 km geographical boundary around Cuneo was a deliberate choice. Without such a constraint, transportation would overwhelmingly dominate the results due to long-haul international travel, making other categories appear negligible. While this information is relevant in absolute terms, it would limit the practical usefulness of the analysis, as long-distance transport emissions largely fall outside the control of event organizers. By narrowing the focus to a regional boundary, the results remain meaningful and actionable: all impact categories remain comparable in scale, and strategies for improvement can be realistically designed and implemented by the organizers. It is important to stress that this does not mean ignoring external impacts; rather, it reflects the need to align the study boundaries with the intended application and the capacity of the organization to act.

- *Phase 3 – Data Collection*: Data collection represents the most challenging and resource-intensive phase of the assessment. The type, quality, and quantity of data gathered directly influence the robustness of the results. In principle, primary data - collected directly from participants, organizers, and stakeholders - should be prioritized. However, sport events present unique difficulties: unlike products, which can be traced through labels, certifications, and established databases, events are dynamic systems shaped by heterogeneous actors, each with their own behaviors, preferences, and impacts.

  For this reason, a flexible approach is often necessary. In this study, registration files provided a solid starting point, offering demographic and geographical information on participants. These were complemented by a survey, a widely adopted tool in event studies, which proved crucial in gathering data on expenditure patterns, length of stay, travel modes, and satisfaction levels. The quality of the survey - its structure, specificity of questions, and response rate - plays a decisive role in the reliability of the results. Conducting surveys on-site, rather than solely online, can further increase representativeness and accuracy.

Equally important is the collaboration with event organizers. They often hold detailed quantitative data such as budgets, materials used and logistical choices, as well as qualitative insights derived from their experience. Interviews and continuous feedback with organizers not only improve data availability but also help validate results, ensuring that they remain grounded in reality. Finally, secondary data from previous studies, scientific literature, or specialized databases can be used to fill data gaps and strengthen the robustness of assumptions. The balance between precision and feasibility must always be kept in mind: if the ultimate goal is communication and awareness-raising, an approximate yet credible estimate of impacts may be more valuable than a highly detailed but impractical analysis.

- *Phase 4 – Impact Assessment*: At this stage, the analysis of environmental, economic, and social dimensions is carried out. A preliminary segmentation of participants (for example, based on distance of origin) increases accuracy and avoids the limitations of aggregated averages.

  For the environmental dimension, the LCA methodology as structured by ISO 14044 [5] provides a solid foundation. The process begins with the creation of an inventory for each analysis area (e.g., energy consumption, transport, food, waste, accommodation), followed by the quantification of emissions and other environmental flows. Given the inherent uncertainty of data, scenario analysis can provide additional robustness: instead of delivering a single value, alternative scenarios, such as conservative and optimized, are simulated. This approach yields a range of possible outcomes, highlighting the sensitivity of results, and illustrating the potential benefits of sustainable practices. Importantly, it also transforms the results into actionable insights, allowing organizers to evaluate concrete strategies for emission reduction.

  The economic dimension requires a different approach, as sport events are service-oriented rather than product-oriented systems. Following the principles of Life Cycle Costing (LCC), this analysis focused on the host territory as the reference system, examining the direct and indirect spending flows generated by participants, visitors, and organizers. Key parameters - such as average daily expenditure, number of visitors per participant, length of stay, and organizational costs - were gathered mainly through surveys and data provided by organizers, then applied to segmented participant categories (local, national, international). This segmentation increases accuracy, ensuring that each parameter reflects the behavior of a homogeneous group. The methodology has the advantage of being easily replicable for different editions of the event: if parameters such as average expenditure remain constant, varying only the number and distribution of participants provides a straightforward way to estimate future economic impacts.

Finally, the social dimension is the most complex to assess in terms of methodology and indicators, as it is inherently less tangible and less standardized. While S-LCA provides useful guidance, it often requires adaptation when applied to events. In this study, the analysis combined quantitative indicators with qualitative evaluation. Ideally, quantitative indicators should be collected to provide objective measures, such as the return rate of participants across multiple editions, satisfaction levels based on Likert-scale surveys, or socio-demographic analyses. However, a purely quantitative approach may overlook important qualitative aspects. For this reason, the social assessment can also include the identification of unique features and practices that characterize the event from a social perspective—such as community engagement, inclusivity initiatives, or side events aimed at increase the audience. By combining measurable indicators with qualitative evidence, the social dimension can capture both the numerical footprint and the intangible legacy left on the host community.

- *Phase 5 – Interpretation of Results*: The final phase is the interpretation of results, where data are translated into meaningful insights and actionable conclusions. Beyond reporting numerical values, this phase seeks to provide a logical narrative: identifying major contributors, highlighting areas of improvement, and contextualizing the findings through benchmarking with comparable events. For instance, comparing results with similar studies allows organizers to evaluate their performance relative to industry standards, giving greater credibility and communicative value to the assessment. Interpretation also offers the opportunity to explore integrative approaches. While environmental, economic, and social results are often presented separately, efforts can be made to develop composite indicators or aggregated scores that reflect the overall sustainability performance of the event. Even if such integration is methodologically challenging due to the heterogeneity of indicators, it represents an important step towards facilitating decision-making and aligning results with the holistic vision of the Triple Bottom Line framework.

This five-phase structure does not represent a standardized or definitive method, but rather a flexible and adaptable framework. Its strengths lie in providing clear guidance for replicating integrated sustainability assessments of sport and cultural events, while remaining open to adaptation and improvement according to context-specific needs.

As already highlighted at the end of Chapter 3, the framework adopted in this research inevitably presents assumptions and, consequently, limitations and criticalities. Some of these are substantial and can significantly affect the outcomes, while others are less critical but still relevant and worth considering.

An important limitation concerns the reliability of the results, which is directly related to data quality. In several cases, primary data were unavailable and the analysis relied on secondary sources, scientific databases, or approximations. This was particularly evident in the environmental assessment of waste management and food and beverage, where assumptions were required to fill data gaps. Data quality strongly influences the robustness of results, especially for the environmental dimension, where accuracy is key. At the same time, given the communicative purpose of this study, rough estimates were sufficient to provide a clear order of magnitude and highlight areas for improvement. Future studies should nevertheless prioritize primary data collection, for example through on-site surveys with larger response rates, richer sets of questions, and more precise answers (rather than using range-based answers). This would increase representativeness, reduce the need for approximations, and ultimately enhance the reliability of the assessment. The underlying assumption that survey respondents are representative of the entire participant base, used in this study, remains a source of uncertainty, although sufficient to extract meaningful insights and draw judgments.

Another critical limitation concerns the definition of system boundaries. Narrowing boundaries can exclude relevant contributions or shift attention away from certain impact areas, potentially biasing interpretation. This is a well-known challenge in the assessment of events, whose heterogeneity in size, scope, and context makes standardization difficult, if not impossible. As discussed in the proposed framework (Figure 5.2), boundaries should be defined across organizational, temporal, and geographical dimensions. These constraints should balance completeness - ensuring all relevant stakeholders, phases, and impact areas are considered - with feasibility, by excluding elements outside the direct influence of organizers or beyond their capacity to improve. This approach helps ensure that results remain meaningful and actionable, rather than being dominated by factors, such as long-haul transportation, on which organizers have no control.

A related issue lies in the variety of methods used in the literature, which makes comparisons across different studies challenging. For instance, some economic assessments focus on expenditures of participants and visitors, while others adopt a cost–benefit analysis from the organizers' perspective. This lack of standardized approaches reduces comparability, highlighting the need for flexible and adaptable but yet comprehensive frameworks like the one proposed in this study.

Looking ahead, further research is needed to test the adaptability of this framework to other event contexts, starting with small to medium scale sport events which structures and participant profiles may be similar, and then extending to larger or different types of events. Such applications would help identify both the strengths and the weaknesses of the approach. Importantly, future studies should place greater emphasis on primary data collection and stakeholder collaboration, investing more resources into building comprehensive datasets and thereby reducing uncertainty.

To sum up, this study recognizes the assumptions and limitations inherent in its design, but, at the same time, the proposed framework offers valuable opportunities for refinement and adaptation. The growing trend towards sustainable event management increases the need for integrated assessments of this kind. Small and medium-sized events, in particular, represent fertile ground for such analyses, as they simultaneously embody the three pillars of sustainability: they boost local economies, engage communities, and embrace environmentally conscious practices to enhance efficiency and attractiveness. This suggests substantial potential for applying and improving the methodology, with the ultimate goal of supporting organizers in designing events that are not just successful but also sustainable.

Chapter 6

Conclusions

The growing interest in sustainability within the sports industry has led to increasing attention on the environmental, economic, and social impacts of events. International standards such as ISO 20121, along with stakeholder expectations, underscore the need for events to adopt sustainable practices not only to comply with regulatory requirements but also to enhance their appeal, attractiveness, and legitimacy [30]. While major events often attract significant attention from researchers, smaller events - despite their strong connections to local communities and their increasing international appeal - remain underexplored and tend to be overlooked. However, these smaller events represent powerful and effective tools for promoting sustainable practices, generating tangible socio-economic benefits, and fostering community engagement.

In light of this context, this thesis has examined the case of the Granfondo La Fausto Coppi, applying an integrated and comprehensive Life Cycle Sustainability Assessment (LCSA) approach to evaluate its performance across the Triple Bottom Line. Building on the framework first introduced by Kloepffer [32], the study embraced a life cycle perspective and a multi-stakeholder approach to assess the environmental, economic, and social dimensions in a coherent and transparent manner.

The methodology was designed to be both rigorous and adaptable. A shared goal and scope definition established the functional unit, system boundaries, and key assumptions across the tree dimensions of analysis: the functional unit was identified as the " preparation and execution of a three-day cycling event with 2,300 participants". The boundaries were set as operational (areas of analysis), temporal (three days of event), and geographical (75 km radius around Cuneo). These constraints ensured that the analysis remained focused on areas where the organizers could realistically influence outcomes, thereby enhancing the relevance of the findings. Data were gathered through participant registration files, a survey with 176 responses, scientific studies, databases, and - crucially - direct collaboration with event organizers, whose expertise allowed a grounded and credible interpretation of the results. To improve robustness and representativeness of results, participants were segmented into local, national, and international groups, based on their distance of origin, reflecting differences in behavior, spending, and impact patterns.

The dissertation provided several key insights. On the environmental side, transport emerged as the dominant contributor to total emissions, even under the restricted geographical boundary. The scenario analysis demonstrated that implementing targeted measures - such as increasing vehicle occupancy, promoting car-pooling, and providing shuttle services - could significantly reduce transport-related emissions. Other effective strategies included selecting local food suppliers, promoting renewable energy use, and improving waste management practices. Overall, a potential reduction of around 20% in total CO_2e emissions was identified, highlighting the tangible benefits of targeted interventions.

From an economic perspective, the event generated an estimated impact of €1.83 million. Most of this came from international participants due to their higher spending and longer stays. These findings underline the dual importance of enhancing international appeal while simultaneously strengthening local linkages, since these types of events deeply rely on a strong domestic base. On the social side, the event demonstrated a strong international profile, with participants from 36 different countries, alongside a remarkable return rate of 53%. This balance between newcomers and returning participants reflects both the enduring appeal of the event and its ability to foster loyalty. The active involvement of local communities, associations, and suppliers further emphasized the event's cultural significance.

Finally, to integrate these heterogeneous indicators, the study employed a radar chart representation and a normalization procedure, setting internal strategic benchmarks as target values. The aggregated performance was then assessed using a distance-to-ideal method, resulting in an overall sustainability score of 75.17 out of 100. While this metric is not intended as an external benchmark, it provides a practical internal tool for tracking progress across future editions and guiding decision-making.

The thesis pursued two primary research goals. The first was to evaluate the sustainability performance of the Granfondo La Fausto Coppi and to communicate results in a clear and actionable manner. This objective was achieved by identifying key contributors, highlighting areas of improvement, and proposing practical strategies for organizers. The second objective was to propose a general framework for assessing the sustainability of small to medium-sized events. A five-phase structure was outlined allowing replication and adaptation to other contexts.

Nonetheless, several limitations were acknowledged. The availability and quality od data represented a major challenge, as relying on secondary data and assumptions introduced some uncertainty. The choice of system boundaries, while necessary to ensure relevance, inevitably excluded some impacts and may have influenced the results. Furthermore, while the integrated score provided a useful internal benchmark, its reliance on internally defined targets makes it unsuitable for cross-event comparison. These limitations highlight the need for transparency when reporting assumptions and underscore the necessity for further research to refine and standardize methodologies.

Looking ahead, future research should test the proposed framework across events of different size and type to evaluate its adaptability and potential for wider application. Greater reliance on primary data, for example through on-site surveys, would enhance robustness of findings, as long as feasibility and relevance are preserved. Strengthening collaboration and partnerships with event organizers remains essential, both for collecting data and for aligning targets with strategic objectives. Over time, the adoption of more standardized approaches could facilitate comparability between events, fostering a competitive drive towards more sustainable events.

In conclusion, this thesis contributes to the ongoing discourse about event sustainability by demonstrating the application of LCSA to a medium-sized cycling event and, more importantly, by proposing a replicable and adaptable framework for assessing sustainability in sport events. While not intended as a universal or definitive method, the framework balances robustness with usability, providing a practical tool for practitioners and a basis for continuous improvement in the planning and execution of events. As small and medium-sized events gain increasing prominence in sport and tourism, their ability to foster sustainable practices and generate tangible economic and social benefits becomes ever more relevant. By raising awareness, informing decision-making, and guiding future planning, the framework developed here represents a step towards setting higher standards of sustainability in sport events, aligning them with the broader societal shift towards sustainable development.

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Appendix A

Questionnaire

Questionario - Granfondo La Fausto Coppi | Generali

Dati socio-demografici

1. Genere

- Uomo
- Donna
- Preferisco non specificarlo

2. Età

- 19-25
- 26-40
- 41-60
- 60+

3. Indicare il Paese di provenienza

- Italia
- Other

4. A quale delle seguenti categorie appartieni?

- Partecipante alla Granfondo (anche se edizioni precedenti)
- Visitatore (non partecipante)

- Appassionato di ciclismo (non presente all'evento)

5. Conoscevi già la Granfondo La Fausto Coppi | Generali?

- Sì, la conosco
- Ne ho sentito parlare
- No, non la conosco

Impatto sociale

6. Ritieni che eventi come la Granfondo La Fausto Coppi | Generali possano favorire lo sviluppo della comunità locale?

- Per nulla
- Poco
- Abbastanza
- Molto

7. Ritieni che eventi come la Granfondo La Fausto Coppi | Generali possano essere considerati eventi sostenibili?

- Per nulla
- Poco
- Abbastanza
- Molto

8. Ordina le seguenti azioni in base a quanto le ritieni importanti ed efficaci per un evento più green e sostenibile

- Maggiore utilizzo di materiali riciclabili
- Più postazioni di riciclo durante l'evento
- Riduzione delle emissioni dei trasporti (es. navette)
- Promozioni di prodotti locali a km zero

9. Hai già partecipato ad edizioni precedenti della Granfondo La Fausto Coppi | Generali?

- No, l'edizione 2025 sarà la mia prima partecipazione
- Sì, ho già partecipato ad edizioni precedenti

10. A quale delle seguenti edizioni della Granfondo La Fausto Coppi | Generali hai già partecipato o parteciperai?

- 2025 (prossima edizione)
- 2024
- 2023
- Edizioni precedenti (2021, 2019,..)

11. Basandoti sulla tua esperienza nelle precedenti edizioni, quanto sei soddisfatto/a dei seguenti aspetti?

- Organizzazione in generale
- Servizi e logistica
- Sicurezza stradale e segnaletica
- Atmosfera e coinvolgimento
- Pulizia e gestione dei rifiuti
- Scala: Molto insoddisfatto/a – Insoddisfatto/a – Neutro/a – Soddisfatto/a – Molto soddisfatto/a

12. Se ci fosse un'opzione eco-friendly per ridurre l'impatto ambientale dell'evento, saresti disposto a pagare qualcosa in più in fase di registrazione?

- Sì, fino al 5%
- Sì, fino al 10%
- No

Trasporto, Alloggio e permanenza

13. Quanti km hai percorso per raggiungere l'evento?

- 0-50 km
- 51-100 km
- 100-300 km
- 300-600 km
- 600-1000 km
- Oltre 1000 km
- Oltre 2000 km

14. Quale tipologia di mezzo hai usato per raggiungere l'evento?

- Auto
- Minivan
- Camper/caravan
- Treno
- Bus
- Aereo corto raggio
- Aereo lungo raggio
- Bici
- Altro

15. Includendo il guidatore, quanti passeggeri erano presenti nel tuo mezzo?

- 1
- 2
- 3
- 4
- 5

- 6
- 7
- 8+

16. Quante persone ti accompagnano all’evento come visitatori?

- 0
- 1
- 2
- 3
- 4
- 5+

17. Dove hai soggiornato durante l’evento?

- Non ho pernottato
- Hotel
- B&B / Airbnb
- Camping
- Ospitato gratuitamente
- Altro

18. Quante notti hai pernottato nella zona dell’evento?

- 1
- 2
- 3
- 4+

Consumi e spese dei partecipanti

19. Durante l'evento, hai speso o spenderesti soldi in una o più di queste categorie?

- Cibo e bevande
- Shopping/prodotti locali/souvenir
- Servizi e attività extra

20. Dove hai consumato o consumeresti i tuoi pasti principali durante la permanenza all'evento?

- Ristorante
- Street food / food truck
- Supermercato o negozio di alimentari
- Pranzo al sacco / Cibo portato da casa

21. Quanto hai speso o spenderesti in media al giorno per persona nella categoria cibo e bevande?

- meno di €10
- €10-25
- €25-50
- oltre €50

22. Quanto hai speso o spenderesti giornalmente nella categoria shopping, prodotti locali e souvenir?

- Non ho acquistato nulla
- meno di €20
- €20-40
- €40-70
- oltre €70

23. Quanto hai speso o spenderesti giornalmente nella categoria servizi ed attività extra?

- Non speso nulla
- meno di €10
- €10-30
- €30-50
- oltre €50

24. Durante l'evento, quanto regolarmente utilizzi i contenitori per la raccolta differenziata?

- Per nulla
- Raramente
- A volte
- Spesso
- Sempre

25. Ritieni che eventi come la Granfondo La Fausto Coppi | Generali possano favorire lo sviluppo della comunità locale?

- Per nulla
- Poco
- Abbastanza
- Molto

26. [Opzionale] Cosa vorresti vedere nella prossima edizione per renderla più green?

Appendix B

Detailed methodology for impact assessment

This appendix includes supplementary procedures and tables that provide the background behind some of the results presented in the main body of the thesis. Including them directly within the chapters would have unnecessarily increased the complexity of the reading and risked overloading the analysis. However, in the interest of transparency, it was considered important to make these materials available.

The tables and procedures reported here were fundamental to the development of the study, even if they are not discussed in detail in the main chapters. They represent the underlying data and calculations from which several results have been derived. In particular, this appendix presents data such as the Life Cycle Inventory (LCI) for the food and beverage category, additional intermediate results, and methodological clarifications such as the procedure used to calculate participants' travel distances.

In this way, the appendix provides supporting information for readers interested in examining the foundations of the analysis in greater detail.

B.1 Procedure for Travel Distance Estimation

This section explains the procedure used to calculate the travel distance for the 2,300 participants, starting from their municipality of residence as reported in the registration data. The Haversine formula, shown in Equation B.1, was applied to compute the Euclidean distance between the event location - defined by its latitude and longitude coordinates - and each participant's place of origin - data obtained from the registration spreadsheet.

$$d = 2R \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1) \cdot \cos(\varphi_2) \cdot \sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right) \tag{B.1}$$

where:

- d = distance between the two points
- R = Earth's radius (6371 km)
- φ_1, φ_2 = latitudes of point 1 and 2 (in radians)
- λ_1, λ_2 = longitudes of point 1 and 2 (in radians)

The reference point (DMS format) for the event location is:

- **Place:** Piazza Galimberti, Cuneo, Italy
- **Latitude:** 44°23′23.95″N
- **Longitude:** 7°32′50.79″E

Since the Haversine formula provides only the straight-line distance (Euclidean distance), an adjustment was necessary to approximate the real travel distance by road, which is typically longer due to geographical and infrastructural constraints. In line with common practice, a correction factor between 1.2 and 1.5 is generally applied. For this study, a coefficient of 1.3 was adopted, meaning that the actual distance was assumed to be 30% greater than the Euclidean distance.

An exception was made for participants traveling from more than 5,000 km away, for whom the correction factor was not applied, as air travel was assumed to be the main mode of transport. In all other cases, the adjusted distance was obtained by multiplying the Haversine distance by the 1.3 coefficient, providing a more realistic estimate of the road travel undertaken by attendees.

B.2 Transport

Table B.1 presents the environmental impact results of transport without applying the geographical boundary. It reports the total person-kilometers (round trip) traveled by participants and visitors across different distance of origin ranges. The table also shows how these person-kilometers are distributed among the various modes of travel, together with the corresponding CO_2-equivalent emissions for each distance range.

Table B.1: Travel distance distribution, transport modes and related CO_2 emissions.

Distance(km)	p-km (round trip)	Bike[p-km]	Car[p-km]	Van/Camper[p-km]	Bus[p-km]	Train[p-km]	Air short-haul[p-km]	Air long-haul[p-km]	Kg CO_2e
0–50	95,625	37,475	56,858	–	1,292	–	–	–	6,480
51–100	86,989	–	73,606	10,037	–	3,346	–	–	9,353
100–300	283,742	–	267,528	16,214	–	20,351	–	–	31,610
300–600	142,459	–	122,108	–	–	20,351	–	–	13,979
600–1000	195,375	–	170,954	24,422	–	–	–	–	21,710
1000–2000	697,941	–	511,823	46,529	–	–	93,059	–	84,709
Over 2000	2,000,434	–	–	–	–	–	–	2,000,434	364,079
								Total CO_2e emissions	**531,818**

*p-km = person-kilometers

B.3 Accommodation

This section of the appendix provides additional details regarding the accommodation category. Table B.2 shows the breakdown of the number of overnight stays of participants and visitors according to their distance of origin and the type of accommodation, including the number of visitors and participants staying overnight and their average length of stay.

Table B.2: Participants and visitors overnights distribution by distance and accommodation type

Participant cat.	Total part.	Overnight participants*	Avg overnight stay	Hotel Overnights	B&B Overnights	Camping Overnights
Local	1351	149	1.0	68	54	27
National	602	455	2.0	541	319	49
International	347	334	3.3	471	514	129
	Total	**937**		1079	888	205

*Average stay of those actually sleeping in accommodation facilities

Visitor cat.	Visitors per part.	Total visitors	Overnight visitors	Hotel Overnights	B&B Overnights	Camping Overnights
Local	1.56	2108	232	105	84	42
National	0.83	381	288	342	202	31
International	0.56	193	186	262	286	71
Total			**705**	709	572	145

Table B.3 indicates the assumed food and beverages considered in the estimation of the breakfast impacts, showing the breakdown of the emission factors across the different stages. All data presented here are taken from Agribalyse 3.2 [1], described also by their specific code (code AGB).

Table B.3: Breakfast emissions breakdown– kg CO_2eq per stage and totals.

Ingredients	Amount [kg]	Code AGB	Production	Transformation	Packaging	Transport	Distribution	Consumption	Total [kg CO_2eq.]
Sandwich	0.13	25485	0.222	0.037	0.117	0.047	0.006	0.001	0.429
Scrambled egg	0.10	22505	0.114	0	0.035	0.031	0.008	0.004	0.192
Yogurt with cereals	0.175	19579	0.107	0.029	0.069	0.046	0.006	0.001	0.259
Fruit juice	0.20	2048	0.029	0.028	0.034	0.045	0.003	0	0.139
Espresso coffee	0.04	18071	0.013	0.001	0.005	0.002	0	0	0.021
								Grand total	**1.0415**
								Breakfast w/o transport	**0.870**

Table B.4: Resource consumption and related CO_2 emissions for Hotel and B&B (assuming transport distance to landfill = 20 km).

Resource	Unit	EF (kg CO_2e/unit)	Consumption Hotel	Consumption B&B	Emissions Hotel	Emissions B&B
Electricity	kWh	0.257	20	10	5.144	2.572
Natural gas	MJ	0.069	7	3.5	0.486	0.243
Water	kg	0.001	300	150	0.1317	0.065
Municipal waste	kg	0.571	1	0.5	0.571	0.285
Waste transport	tkm	1.31	0.03	0.02	0.0393	0.026
				Breakfast	1.041	1.041
				Total	**7.413**	**4.234**

B.4 Food and Beverage

This section presents the complete Life Cycle Inventory (LCI) for the Food and Beverage category. Table B.5 reports the list of all ingredients used in the meals provided by the organization, the total quantity of each ingredient, and the corresponding emission factors. All values were sourced from Agribalyse 3.2 [1].

Serving sizes are derived from online recipes, manufacturer's website, and catering serving recipes. This data was used when calculating the weight of each food item servend, which is then used to determine total impact of food and beverage.

Table B.6, taken from the study by Fieschi and Pretato, presents a comparative assessment between biodegradable and compostable cutlery and traditional tableware [20]. The analysis also includes the mass of organic waste generated to serve 1,000 meals, which was defined as the functional unit of that study.

Table B.6: Materials and waste production referred to the functional unit of 1000 meals (Fieschi and Pretato [20])

Cutlery	**Compostable**		**Traditional**	
	Material	**Mass (kg)**	**Material**	**Mass (kg)**
Dinner plate	PLA	12.9	GPPS	10.9
Knife and fork	Mater-Bi	7.6	HIPS	6.3
Cutlery pack	PLA	1.4	PP	1.2
Cup	Mater-Bi	4.4	GPPS	2.5
Tray and napkin	Paper	7.8	Paper	7.8
Organic waste		150		150
Total weight		184.1		178.7

Table B.5: Meals and supplies — amounts and total emissions (kg CO_2eq) [1].

Meal/Area	# meals	Ingredient	Amount/meal [kg]	Total mass [kg]	Total [kg CO_2eq.]
Tomato Pasta	1600	Pasta cooked	0.200	320.000	321.35
	1600	Tomato Sauce	0.100	160.000	129.41
	1600	Olive Oil (EV)	0.010	16.000	43.97
	1600	Parmesan	0.010	16.000	36.04
Beef	1600	Braised Beef	0.100	160.000	1983.15
	1600	Olive Oil (EV)	0.010	16.000	43.97
	1600	Onion	0.070	112.000	42.91
	1600	Carrot	0.070	112.000	40.54
	1600	Celery	0.050	80.000	55.97
	1600	Red Wine	0.150	240.000	298.37
	1600	Butter	0.008	12.000	29.11
Fruit and dessert	1600	Apple	0.250	400.000	147.54
	1600	Wafer Balocco	0.090	144.000	0.22
Water	1600	Bottle of water	0.565	904.000	289.56
Feed zone	2300	Parmesan	0.005	10.5	23.65
	2300	Coca-cola	0.320	737.1	360.35
	2300	Instant coffee	0.001	1.4	1.78
	2300	Instant tea	0.001	1.4	0.04
	2300	Toast bread	0.014	33.25	34.06
	2300	Roasted ham	0.001	2.8	12.90
	2300	Salami	0.002	5.6	23.93
	2300	Jam	0.007	16.8	35.06
	2300	Chocolate spread	0.003	6.3	15.63
	2300	Wafer Balocco	0.003	6.3	15.14
	2300	Biscuits Balocco	0.001	2.94	6.77
	2300	Fruit tart	0.011	24.85	43.00
	2300	Banana	0.060	138.6	106.98
	2300	Apple	0.030	70	25.82
	2300	Orange	0.012	28	16.98
	2300	Lemon	0.003	7	4.43
	2300	Almond	0.005	10.5	26.00
	2300	Walnut	0.003	7	26.82
	2300	Dried Apricot	0.008	17.5	49.33
	2300	Apple dried	0.008	17.5	27.91
	2300	Ginger	0.001	2.8	1.36
	2300	Sugar	0.002	4.9	3.61
	2300	Bottle of Water	0.301	693	221.98

B.5 Waste Management

Table B.7: Waste management emission factors (EF) sourced from Ecoinvent v3.9.1. [16].

Category / Process	EF	Unit	Notes
Worst-case scenario (landfill and composting)			
Landfill of plastic waste	0.072	$kgCO_2e/kg$	Landfill of plastic waste at landfill site; includes landfill gas utilisation and leachate treatment; excludes collection, transport and pre-treatment.
Waste transport	1.31	$kgCO_2e/tkm$	Municipal waste collection service by 21-metric-ton lorry.
Landfill of municipal waste	0.571	$kgCO_2e/kg$	Treatment of municipal solid waste (MSW), sanitary landfill.
Landfill of paper waste	0.214	$kgCO_2e/kg$	Treatment of waste graphical paper, sanitary landfill.
Landfill of plastic waste	0.101	$kgCO_2e/kg$	Treatment of waste plastic (mixture), sanitary landfill.
Landfill of glass waste	0.0107	$kgCO_2e/kg$	Treatment of waste glass, sanitary landfill.
Compost (biowaste)	0.0831	$kgCO_2e/kg$	Treatment of biowaste, industrial composting.
Best-case scenario (recycling, composting and incineration)			
Waste incineration of MSW	0.327	$kgCO_2e/kg$	Incineration of municipal solid waste in average European waste-to-energy plant; excludes collection, transport and pre-treatment; no credit.
Compost (biowaste)	0.0831	$kgCO_2e/kg$	Treatment of biowaste, industrial composting.
Recycling (generic)	0	$kgCO_2e/kg$	Cut-off, no benefit approach.
Paper (recycling)	0	$kgCO_2e/kg$	Cut-off, no benefit approach.
Waste transport	1.31	$kgCO_2e/tkm$	Municipal waste collection service by 21-metric-ton lorry.

B.6 Economic Impact

Table B.8 reports the breakdown of daily expenditures across the three considered categories - food and beverage, shopping and goods, and extra activities such as museums or other events. Respondents were asked to indicate their spending by selecting a range of per capita daily expenditure for each category, rather than providing an exact value. This approach helped reduce uncertainty, as open-ended questions often lead to inconsistent or unreliable answers. Each range was then associated with an average value, enabling the calculation of mean daily expenditure per participant, further disaggregated by spending category and by distance of origin.

Table B.8: Breakdown of spending categories by travel distance (€/day)

Distance [km]	**Spending distribution**			**Daily spending**
	Category 1	**Category 2**	**Category 3**	**(€)**
0–50 km	18.75 €	15.68 €	3.72 €	38.14 €
51–100 km	18.94 €	17.88 €	4.81 €	41.63 €
100–300 km	31.07 €	27.71 €	7.00 €	65.79 €
300–600 km	33.57 €	31.43 €	5.00 €	70.00 €
600–1000 km	37.81 €	31.88 €	5.63 €	75.31 €
1000–2000 km	36.50 €	21.67 €	5.67 €	63.83 €
Over 2000 km	38.13 €	48.75 €	6.25 €	93.13 €
Average expenditure	**30.68 €**	**27.86 €**	**5.44 €**	**63.98 €**

Notes: Category 1 = food & beverages; Category 2 = shopping; Category 3 = events & extra services.