

Article

# Soft Drink Supply Chain Sustainability: A Case Based Approach to Identify and Explain Best Practices and Key Performance Indicators

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Received: 7 August 2018; Accepted: 29 September 2018; Published: 1 October 2018



**Abstract:** Environmental regulations and sustainable developments are forcing industries to assess, optimize and improve their processes to minimize costs and increase the efficiency of industrial sustainability dimension. This effect is more evident in the food industries due to the high impact that this sector has on environmental and economical sustainability, considering the primary role of packaging systems, the huge water consumption both for the production and the cleaning processes or the energy utilization related to the treatment plant or to the raw material production. Thus, the aim of this study was to review the current state of soft drink supply chains with respect to industrial sustainability issues. For this reason, a comprehensive literature review was performed to understand what sustainable best practices and key performance indicators are largely applied to soft drink supply chains and then a comparison with two soft drink case studies was proposed to identify if there is a positive correlation between the literature and practical activities. The proposed case studies were thoroughly analyzed highlighting how the production process impacts on sustainability and pointing out potential best practices and key performance indicators. The key conclusion of this study is, on the one hand, to depict the current set of sustainable best practices and key performance indicators which companies performed according to the literature review and, therefore, revise the actual body of the literature, and, on the other hand, to figure out which of these best (or proper) practices and key performance indicators are also implemented in the real world, helping companies to make decisions.

**Keywords:** soft drink supply chain; industrial sustainability; sustainable best practice and Key Performance Indicators (KPIs)

## 1. Introduction

In the last few years, the volume of goods traded internationally, the world's industrial production and the rate of the global consumption of fossil fuel have drastically increased. These factors have caused several challenges related to existing industrial systems and infrastructure including production, distribution, and consumption. Indeed, in the next 30 years, the global industrial system is expected to double its output reducing the current resources and generate 20% of current CO<sub>2</sub> [1,2]. Therefore, a very different “low-carbon, resource-efficient” approach could be achieved by focusing on the industrial system as central to the world economy. Research studies highlight that currently the main industrial issues in sustainability are related but not limited to the following areas: global warming

gas emission from industry, energy in manufacturing and waste as “commercial and industrial”. Consequently, the need to reduce or contain the ecological footprint of the industry will affect the whole industrial system. Companies that want to address these issues should be prepared for this transformation by reducing the resource—and energy—intensity in producing existing goods, investigating the options for a thorough redesign of the industrial system and rethinking business models [3]. Thus, the redesigned industrial system should: (i) add the same value with a reduction on input materials and energy; (ii) use discarded extracted materials; (iii) use benign materials that can be reused according to “cradle-to-cradle” concept; (iv) recycle and reuse sophisticated long-lasting components; and (v) mimic and nurture environmental niches [2]. These factors have been included in the Industrial Sustainability (IS) topic. According to Tonelli et al. (2013), industrial sustainability (IS) “refers to the end state of a transformation process where industry is part of, and actively contributing to, a socially, environmentally and economically sustainable planet” [4]. At the same time, according to Chaudhary et al. (2018), food systems are at the nub of at least 12 of the 17 Sustainable Development Goals (SDGs), which refer to holistic approaches that embody previously “siloesd” food sustainability assessments [5]. They carried out a first study quantifying the status of national food system performance of more than 100 countries, employing different sustainability indicators classified into seven domains as follows: nutrition, environment, food affordability and availability, sociocultural well-being, resilience, food safety, and waste. In this context, high relevance has been given to sustainability by all Food and Beverage (F&B) supply chain actors. Indeed, they are required to be more aware of eco-sustainability because of the increasing of the general concern with environmental and health issues [6–8]. For this reason, this research addressed the IS topic focusing on this relevant industrial sector, in particular the soft drink sector.

The soft drinks industry is a very competitive sector characterized by numerous smaller companies and dominated by few multinationals. Its consumption has increased substantially over the last 50 years. Moreover, its demand has shifted due to changes in consumers’ behaviors. The soft drinks market represents 14.03% of the Consumer Packaged Goods (CPG) marketplace, making it an interesting application domain to improve IS performance. Soft drinks sector is not just growing in consumption but is also constantly evolving as companies are forced to invest in research, innovation, and development to be competitive and respond to market requests [9]. At the same time, new marketing strategies are required and are often more important than the product itself in satisfying new consumers’ needs [10].

Different trends are currently affecting this industry, such as: (i) the increase in Health-Conscious Consumers and the rise of healthy foods and beverages [11]; (ii) the growing consumption of premium quality products [12], and challenges due to legislation and compliance to standards [13]; (iii) the high complexities due to the huge packaging variety [13]; (iv) the large price increases in raw materials in recent years [14]; and (v) the decreasing willingness to pay for the consumption of standard F&B products [15]. Moreover, many studies have investigated the link between soft drink consumption and the increase of obesity, especially concerning children [16]. This is the main reason for the distinction between classic and low calories soft drinks.

For these main reasons, the authors decided to focus on the soft drink’s sustainability topic, with the main aim to help companies to fill the gap of assessing and improving sustainability performance, focusing, in particular, on the water and packaging topics.

To this end, two main trends have to be considered:

- the high complexities due to the huge packaging variety since the packaging must play its part in safeguarding the beverage, offering appropriateness to the intended outlets and affording maximum convenience to the consumer [17]; and
- the huge water consumption in the production process and as the main component of the soft drinks itself [18].

The main objective of this work was to understand how companies operating in the soft drinks sector could benefit, based on the sustainability trend, from assessing, measuring, and enhancing their processes.

As previously stated, sustainable best (or proper) practices and Key Performance Indicators (KPIs) have been defined with a particular focus on two main aspects: water consumption and packaging. These are the two features that mainly impact the soft drinks supply chain operations.

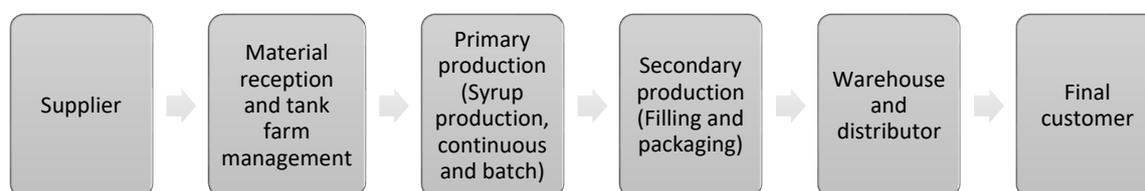
The final expected outcome of this research allows:

- (i) depicting the current set of sustainable best practices and KPIs which companies perform according to the literature review and, therefore, revise the actual body of the literature; and
- (ii) finding which of these best practices and KPIs are also implemented in the real world, helping companies to have a better decision-making framework.

The remainder of this paper is structured as follows. Section 2 explains the main concepts of the study to define key terms and processes related to soft drink supply chains (SDSCs). Then, in Section 3, the research methodology is described, going through the case study. In Section 4, a literature review is presented, focusing on the state of the art of SDSC sustainability to define best practices and KPIs towards packaging and water consumption. In Section 5, the case study findings in terms of best practices and KPIs are shown and then a comparison between the case studies and literature is proposed to identify if there is a positive correlation between them. Finally, Section 6 summarizes the conclusions.

## 2. Research Background

Soft drinks generally include non-alcoholic beverages, such as bottled water, sugar-sweetened beverages, carbonated beverages, sport drinks, energy drinks, diet drinks, fruit beverages, juice drinks and fruit-flavored drinks [19]. As shown in Figure 1, SDSCs present a multi-stage structure.

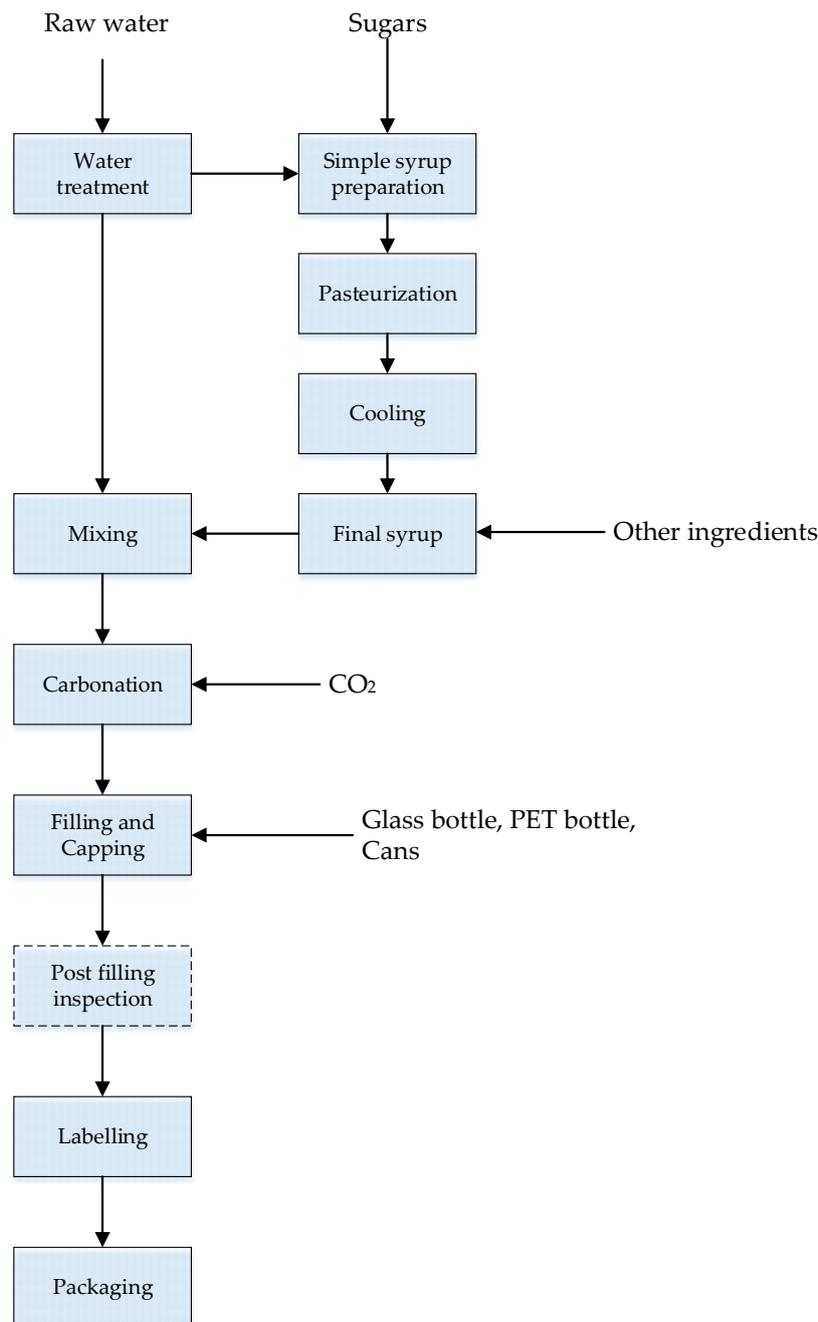


**Figure 1.** Example of a generic Soft Drink supply chain.

SDSCs are largely dependent on the syrup producer, as this is the driver for most downstream operations. The majority of SDSCs follow similar steps, moving from syrup producer, to the bottler, to the distributor, and to the final consumer. The locations of the syrup manufacturers and the bottlers are closely linked to the locations of strategic raw materials and major population. Once soft drinks are bottled and ready for distribution, a variety of distribution channels are leveraged to get the final product to the end consumer.

While the soft drink production processes differ by product type and application, the basic process is the same. A design for a plant for water or juice treatment or soft drinks is always dependent on the respective requirements of the plant, such as diversity of products, level of automation, necessary versatility, the manner of preparing the drinks' components and the required form of quality management. In addition, the provision and control of supporting utilities are essential to ensure that the plant operates continuously, safely and efficiently.

A general trend is also obvious in processing technology for water, soft drinks, and juice: bottling companies are seeking integrated solutions that are optimally designed and set up by one single contact, while at the same time being able to use components from different manufacturers. Figure 2 represents a general scheme of a process plant for soft drink.



**Figure 2.** Soft drink supply chains processing plant.

The first step in the production of soft drinks is the syrup preparation. The syrup is a sugar and water solution, in which sugar or glucose can be used, while diet drinks are prepared using sweeteners or a combination of sugar and sweeteners. Basic components used for beverages can be in powder, liquid or concentrate form. Then, suitable dissolving methods, mixing processes, and heating and filtration steps are used to make the base for the individual syrup variants. Once the syrup has been prepared, it can be bottled. In the bottling step, the syrup is mixed with the main ingredient, water. The exact quantity of syrup and water to be used are crucial in this step. Then, the mixture is carbonated. Feedback control systems are required to ensure that the product carbonation is kept within specified limits. The packaging process consists of filling cans or bottles with soft drinks. After the filling process, the soft drinks are sent to the distributor, who can repack the drinks in smaller quantities or deal directly to the final customers [20].

### 3. Research Questions and Methodology

Case study was used as the research methodology [21] and assumptions, hypotheses and research questions were asked to define the boundaries. It is important to underline that the results provided in this study are limited to companies that operate in the aforementioned outlined environment and present the same or similar characteristics of the case studies adopted for this study.

#### *Assumption*

Soft drinks sector is under pressure by environmental regulations and sustainable developments which are pushing industries to minimize their costs and increase their efficiency. This effect is more evident in this industry due to the high impact that this sector has on packaging systems, water consumption and energy utilization. This sector needs to be: (i) measured and controlled with appropriate KPIs; and (ii) managed and optimized with proper best practices.

The main objective of this study was to understand how SDSCs could benefit from the sustainability standpoint. Therefore, the following hypotheses can be deduced:

**Hypothesis 1.** *Water and packaging are critical factors for SDSCs.*

**Hypothesis 2.** *There are specific KPIs for SDSCs.*

To test these hypotheses, two research questions were identified (Table 1).

**Table 1.** Research questions.

Research Question
<b>RQ1:</b> What are the main water and packaging sustainable best practices in the soft drink supply chains?
<b>RQ2:</b> How do soft drink supply chains measure sustainability?

This analysis required different typologies of data collection, such as data coming from scientific literature and reports. First, to identify the current state of academic insight about SDSCs sustainability, a review of the existing literature was carried out. Section 4 frames the phenomenon through the analysis of the previous academic studies. Then, a framework based on the literature review was developed to define sustainable best practices and KPIs for the soft drink sector.

The aforementioned framework was evaluated through two case studies. The framework was presented to each company and data collection was conducted mainly based on semi-structured interviews with key informants of the companies. Interview data were complemented by published documents and company websites. During interviews, concrete examples were asked to illustrate generic statements.

The next phase was dedicated to defining and contacting companies for the study. To obtain significant results, personnel working in the departments of R&D and Supply Chain (SC) were contacted to participate in this research. The authors selected these specific company positions because of their superior knowledge in the field of investigation. We believe that the SC Manager has a vision of the whole SC process in terms of materials, equipment, suppliers and overall performance, while the R&D Manager investigates technology, concepts and new product development.

Each manager highlighted company strengths/weaknesses and identified strategic business requirements and impediments with respect to packaging, water usage and performance measurements. The interviews were recorded and transcribed to allow a better analysis process. Finally, literature and case study results were compared.

#### 4. Literature Review

This article describes the SDSCs and the contribution of sustainability in achieving them. A qualitative but structured literature review was developed to analyze: (i) the body of the literature about SDSCs related to sustainability; and (ii) all variances and alternatives to produce carbonated soft drinks. For this purpose, material and operational models were analyzed and material transformation, production and quality operations were identified. Literature review was chosen because it is considered a suitable research methodology which provides a brief but comprehensive description through the support of quantitative and qualitative details [22].

The literature review process was performed using Scopus as a scientific database. Authors selected this database because it covers an ample field of journals. Academic papers were filtered through a keyword search regarding the aforementioned field. The set of keywords were “soft drink” AND “supply chain”. At this point, it is fundamental to underline that it was consciously decided to not apply “industrial sustainability” as a filter with the scope of analyzing a wider range of the literature. “Industrial sustainability” practices were selected in the next step. The authors did not set any time restrictions on the publications, restrictions on the type of publications were set, including only articles from journals but no conference papers or book chapters.

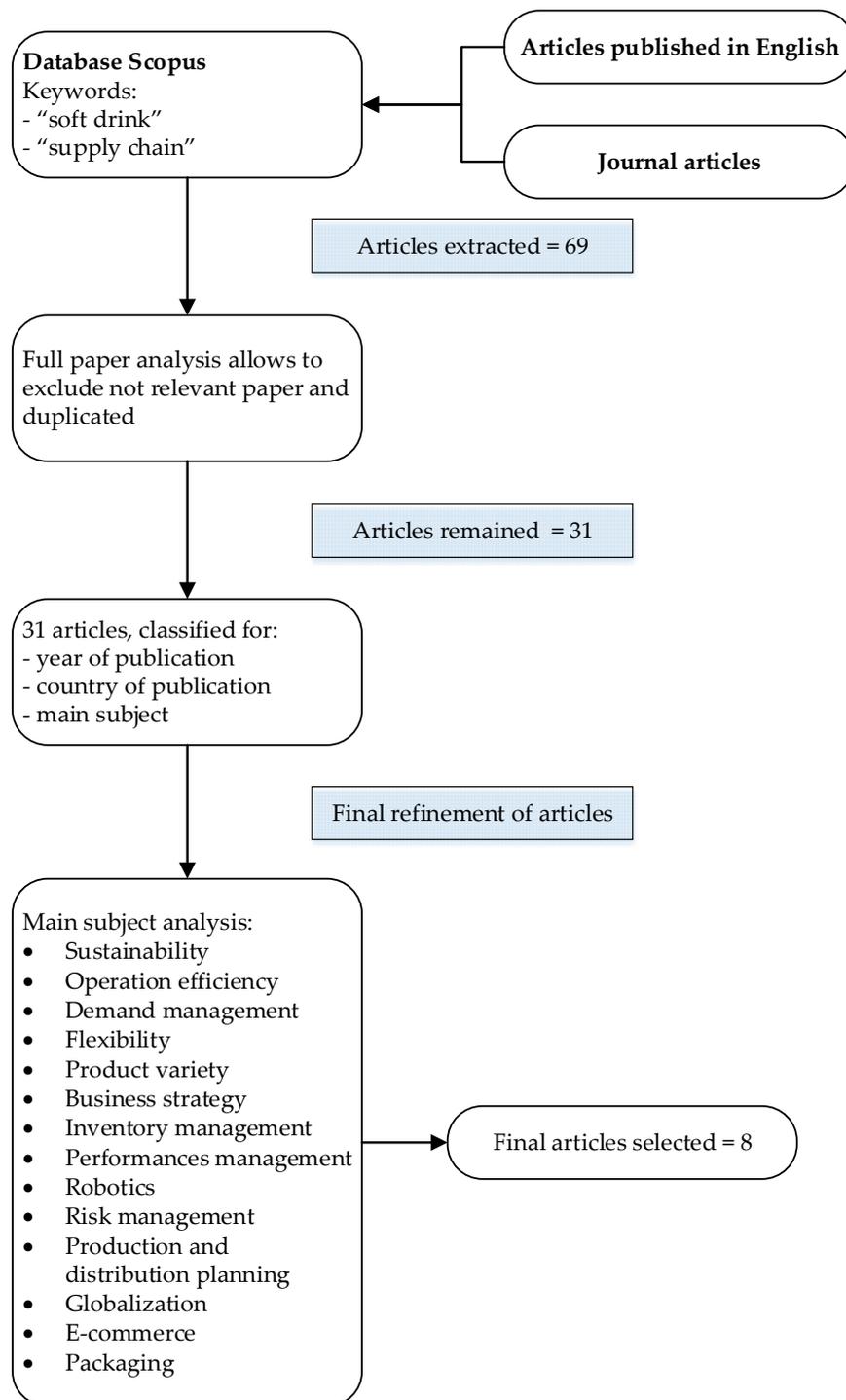
We identified 69 academic papers, which were rigorously reviewed to evaluate their adherence to this study. After reading all the papers, 38 were eliminated and 31 were accepted for further analysis. Of the 38 papers that were excluded, some were duplicated and some were not relevant to the study; in fact, they were focused on different fields such as Biochemistry, Genetics, Molecular Biology or Medicine. Then, the selected database was analyzed according to the country, publication year, and their principle trends. The whole review process is summarized in Figure 3.

Numerous papers have examined demand management and product variety strategies. For example, Reference [20] studied the impact of product variety on demand in the SDSCs. The author claimed that they use modular production such as standardized packaging and labels to reduce operational costs and offer a diverse portfolio. In particular, Reference [23] analyzed how operational costs change with respect to variety and introduction of new products. He observed that, if the product variety increases, product demand for the new variety also increases but the rate of overall demand decreases. This means that a more diverse portfolio leads to more demanding customers which request a high variety of products, thus involving an increase in overall costs.

Reference [24] developed a conceptual model for analyzing soft drink manufacturing companies; his model defines factors and information that affects demand. The framework is based on the identification of demand factors and through a regression analysis developed for each product, and seeks to define the degree of importance of these factors in promotional sales to help companies in the decision-making process and support the collaboration between retailer and producer.

While much research has focused on “inventory and distribution” issues, reference [25] analyzed the problems of “planning production and distribution”. They proposed a hybrid solution based on simulation techniques and mixed integer programming, which allowed solving the planning and scheduling problems of production and distribution. In particular, the model describes different common situations, such as back ordered demand and overstocked inventory. Reference [25] demonstrated the merit of this hybrid model since it performs in a more realistic manner with respect to the individual approaches.

Finally, reference [26] analyzed the distribution problem related to the transportation costs due to the multi-stage structure of SDSCs, focusing mainly on dynamic transaction and vertical integration. They claimed that there is a correlation between dynamic transaction costs and vertical integration; in fact, dynamic transaction costs are defined as “the costs of not having the capabilities you need when you need them”. Moreover, vertical integration is a core requirement to react rapidly to market changes and therefore reduce transaction costs.



**Figure 3.** Structure of methodology adopted for the literature review.

Moving to the quantitative data analysis, Figure 4 shows that there is an increase in the number of papers regarding this topic, especially in the last six years. This could be caused by food and environmental regulations as well as the complexity and globalization challenges, which are affecting the entire process of production and distribution.

Regarding the geographical distribution of data, many countries contribute to this area of research. The USA emerges as where this topic is primarily rooted, followed by countries in Europe and the rest of the world. There is an emerging contribution of scholars from Brazil and India. This suggests the relevance of this topic also for developing countries.

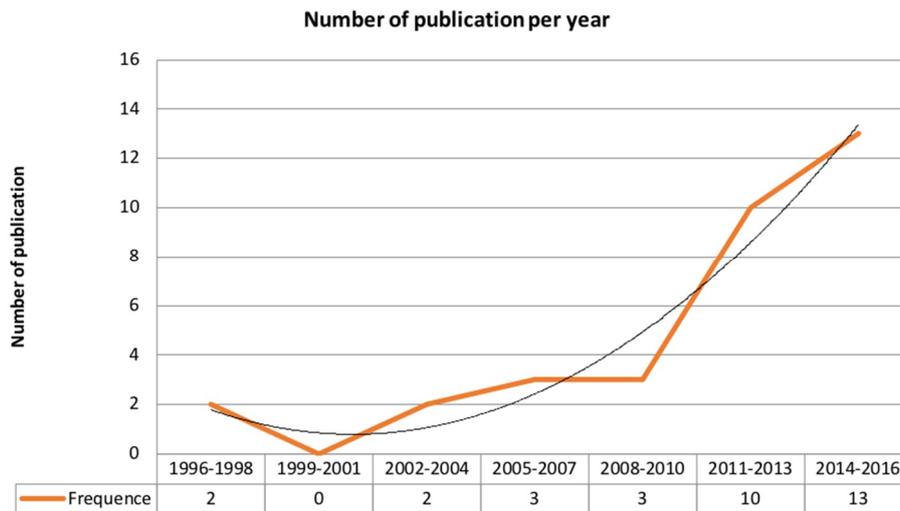


Figure 4. Number of papers by publication year.

Finally, academic papers were examined regarding their major trends, and fifteen trends were found. As shown in Figure 5, it is fundamental to underline the primary role of sustainability, which accounts for eight papers, but an important role is also provided by the trends “operational efficiency” and “demand management”, which assume an important role because of the recent changes from a supply-based approach to a demand-based approach, the so-called “chain reversal”, in which the consumers tell producers what they want to consume. Furthermore “flexibility” and “product variety”, which represents only 7% of the database, seems to be gaining relevance in response to current challenges of mass customization and complexity, as confirmed by the year of publication (2012, 2015, and 2016) versus trends (e.g., “business strategy”) that have the same weight but are older. This analysis allows us to understand that sustainability is a prime objective of SDSC; in fact, it is the most analyzed trend, represented by 25% of the papers, followed by the second main trend (“operational efficiency”) with 10% of the papers.

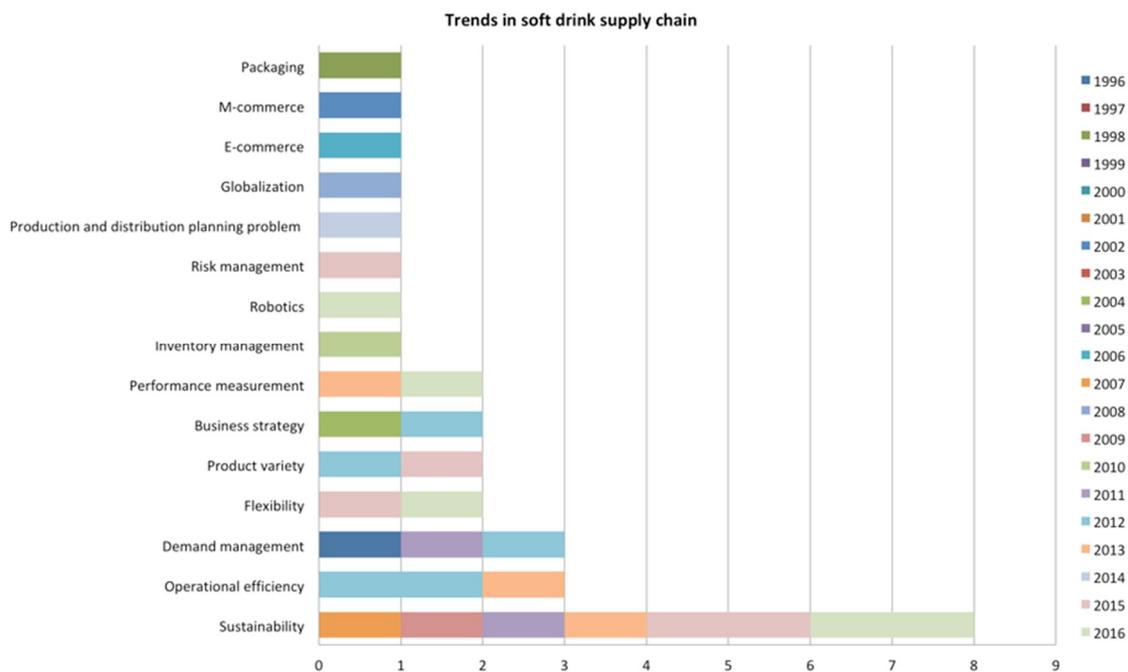


Figure 5. Number of papers by trend.

#### 4.1. How Soft Drinks Supply Chains Address Sustainability

In this section, papers focusing on sustainability issues (Table 2) were analyzed to investigate and identify which issues afflict SDSCs and how they react to these challenges.

**Table 2.** Sustainable dimension analysis.

Author	Sustainability Dimension	Topic	Evaluating Method
Hanssen (2007) [27]	Environmental	Environmental and resource efficiency and effectiveness	LCA
Romero-Hernandez (2009) [28]	Environmental	Packaging	LCA
Ercin (2011) [29]	Environmental	Water footprint	Environmental impact assessment
Bø (2013) [30]	Environmental	Packaging	Data-based approach
Luz (2015) [31]	Environmental	Performance	LCA
Wen Hsu (2015) [32]	Environmental & Economic	Water recycling/reuse	Cost analysis
Alkaya (2016) [33]	Environmental & Economic	Water recycling/reuse	Cost analysis
Shamsi (2016) [34]	Environmental & Economic	Packaging	Chemical analysis

The literature review highlights that companies belonging to the soft drinks sector are dealing with the sustainability topic mainly from the environmental perspective rather than the economic and the social points of view. Indeed, most papers debate themes such as:

- Alternative sustainable energy
- Waste management and recycling
- Packaging
- Water footprint
- Water recycling

A direct focus on the environmental issue could be justified by the increasing appearance of new regulations, which try to limit the impact of production processes. Moreover, the second most relevant point of view is the economic impact. This is due to the rising costs of the raw materials and energy, while the social perspective is not analyzed at all. In Table 2, most papers found in the literature address the sustainability aspects with a specific focus on water and packaging. The fact that the literature focuses more on these features clearly reflects their relevance. This empowered the author's decision to focus on those particular topics (Hypothesis 1).

Concerning the packaging, the literature review analysis shows that the papers about this topic deal with: (i) environmental impact; (ii) eco-design and recycling; and (iii) PET recycling and reuse.

- **Environmental impact** of the packaging systems emphasizes polyethylene (PET) containers. The scope of the analysis was to use this as a basis for decision making in environmental policy; the simulation model shows that “although the total PET volume collected will increase constantly, the recycling rate will eventually decrease. This is due to the fact that the PET production rate will be higher than the PET collecting rate” [28].
- **Eco-design and recycling** was analyzed based on the greenhouse gas emissions of using refillable polyethylene terephthalate (REF-PET) and non-refillable polyethylene terephthalate (NR-PET) in the Norwegian soft drink and carbonated water market [30]. Results show that the emissions from the production and transportation of the two types of bottles are similar, however NR-PET bottles generate 18% less CO<sub>2</sub> emissions than REF-PET bottles. Based on these findings, we suggest that the Norwegian market should change regulations on beverage bottles.
- **Recycling and reuse** analysis considered experimental production of novel value-added materials from PET waste. PET waste can be depolymerized by glycolyzing it with MPD. This polyester diol has the potential for further reactions to produce various products. The polyurethane samples, obtained from PET waste, could be used in various applications, such as industrial parts, membranes and O-rings. The necessity of finding a simple economic method for recycling PET waste is a key concern for sustainable recycling. In fact, it not only serves as a partial solution to

the solid-waste problem, but it can also be regarded as a source of raw material to some industries and thus can also contribute to the conservation of raw petrochemical products and energy.

Concerning the water, the literature review analysis shows that the papers concerning this topic deal with: (i) the water footprint; (ii) water recycling and reuse; and (iii) industrial symbiosis. Specifically, the covered topics are:

- **Environmental Impact assessment:** The paper dealing with this topic focuses on water footprint of the bottle, other packaging materials, paper and energy used in the factory [29]; all water used for production processes and general purposes is “collected and treated in a public wastewater treatment plant before it is returned to the environment”. It emphasizes the importance of returning the water used by companies to nature with the aim of reducing the impact on the local water system.
- **Recycling and reuse:** Closed-loop water recycling systems and the practice of water reuse for fruit washing were introduced to save water and associated costs in the company. A major motivation of company managers taking part in this study was to secure economic benefits in addition to conservation of water resources [33]. The authors considered two best practices:
  - reusing cooling water in the washing process; and
  - adopting a closed-circuit cooling system.

The application of those activities allowed reducing cooling water consumption by 85.2% and the company cooling water demand by 91.8%.

- **Industrial symbiosis:** Wastewater, through sewage treatment services and using the organic material in the wastewater, could be used as the input material for hydrogen fermentation [32]. Industrial symbiosis presumes that industries collaborate intentionally and organize themselves to reach not only a better usage of materials but also a partnership that permits to share strategies and objectives. The symbiotic process described by [32] allows reducing carbon emissions and increasing the adoption of sustainable energy. The commercialization of such energy is still limited by the high production costs of dark fermentative hydrogen. In fact, despite the advantages of industrial symbiosis, it also introduces some challenges to its implementations:
  - regulatory barriers which may prevent the transfer of waste; and
  - cost of reusing waste streams, which may outweigh the benefits, especially when byproduct use is not a significant economic driver for a firm.

Table 2 shows, for each paper belonging to the final sample, the methods used to evaluate the sustainable impact. The most used evaluating mythology is LCA. In this paper, the evaluation methodology study is not addressed.

#### 4.2. Packaging Best Practices

In this section, best practices related to the packaging are defined based on the literature. Today’s packaging assumes a key role and its development is more diversified, integrating the following functions:

- protect beverages from the external environment;
- transmit information to consumers; and
- fulfill transportation and distribution.

While assuming a primary position in waste reduction [35–37], the packaging itself represents a huge part of the whole waste production in the beverage sector [38]. It is necessary to underline that packaging is a fundamental means of protecting and preserving the beverage properties [39,40].

On the one hand, it is important to control its weight and composition to reduce environmental impact, while, on the other hand, it is fundamental to use the correct quantities needed to extend the products' life and therefore reduce the probability that beverages cannot be consumed. Overall, the production phase of beverages has a huge impact on the environment.

Another relevant aspect of packaging is its design [41,42]. Currently, the trend of mass personalization is also reaching the beverage sector. There is an increased service for personalized products in terms of individualized packaging such as the possibility to have one's own name on it [43]. Therefore, packaging remains a huge challenge, where the companies need to arrive at a balance between customer demand, product protection, and sustainability. Improvements of the production processes, the introduction of new technologies and recycled materials have allowed the drastic reduction of PET consumption, energy costs, and waste production (Table 3) [5,43–46].

**Table 3.** Best practices for packaging.

Best practice	Description
<i>Light weighting</i>	Lightening of packaging in accordance to the regulations and legislations.
<i>Usage of recycled material</i>	It allows the reduction of raw materials consumption and non-renewable materials.
<i>Upcycling</i>	The packaging already consumed is used as "raw materials" for other production processes.
<i>Design of "Bio plastic bottle"</i>	Usage of natural materials as raw materials for packaging. An example is the application of endive root or wood waste for the bottles production.
<i>Adoption of more efficient technologies</i>	Application of new generation machine, such as new blower machines, which reduces the consumption of compressed air or the adoption of new generation of blow moulding machine, which allow reducing energy consumption.
<i>Evolution of collection models</i>	Independent models for the collection of waste bottles are being implemented by SDSC, in order to recovery raw materials. In this direction they are also considering incentive models for the consumers.

#### 4.3. Water Best Practices

In this section, best practices related to water are defined from a literature point of view. Facing the increasing global water crisis [47], it is fundamental for the soft drink sector to preserve this valuable resource and adopt strategies for its efficient and safe consumption [48]. Today's production plant employs innovative technologies, which allow the recycling and reusing of water and reduces significantly the need to acquire water from external suppliers [49,50]. The water crisis is defined as the greatest threat that our planet faces, from arid agricultural areas to the possibility of millions of people having no access to water [51,52]. The water crisis impacts both industrialized and developing countries. Each sector of industry has to reinvent itself to minimize its water consumption. In this context, soft drink industries have carried out huge investments in the development of technologies and processes, which allow the reduction of water requirements and permit efficient water recycling. Specifically, SDSCs are the forefront in this issue; in fact, huge amounts of water are used in both syrup production and bottling processes. Water is used as raw material, as a degreasing agent, and for boiling and cooling. Treated water can be desalinated, and organic products can be removed with the aim of fulfilling conditions of water reapplications. Beverage industry's standards specify that water treated with intent for reuse must be at least the same quality as mains water [18,53]. The principle recurring activities in water treatment are shown in Table 4 [54–58].

**Table 4.** Best practices for water treatment.

Best practice	Description
Reduction	Consume less water to produce beverages, and then reduce water withdrawal
Recycling and treatment of wastewater	Recycling water to make it safe to be used in the beverage, the production processes, or released into the environment
Rainwater recovery	Systems of capturing and storing rainwater in tanks or lagoons
Innovative technologies for cleaning processes	Automatic cleaning of the line ducts for changing flavours in the process system that saves water and energy
Engagement with suppliers, especially those in agriculture	Wastewater recovered is used for the irrigation of supplier fields

#### 4.4. KPIs for the SDSCs

In this section, KPIs related to SDSCs are defined from a literature point of view. Even if it is a relatively new research area, sustainability already shows an interesting number of measures and metrics mainly de-structured and at very different levels [59,60]. From the 100 sustainable measured collected in [61], we selected those KPIs for SDSCs. The whole process is depicted in Figure 6.

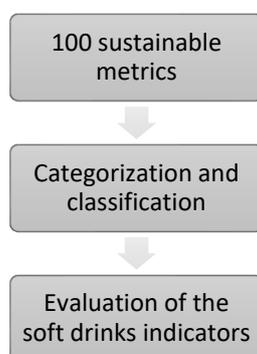


Figure 6. Steps for the soft drink indicators' evaluation.

Therefore, to address this challenge the authors collected sustainability KPIs for SDSCs that they grouped into four main sections: General Aspects, Materials and Packaging, Water and Energy, and Emissions [62].

- *General Aspects* include safety, security and customer satisfaction. This section considers objectives that are not specific on how to improve the manufacturing processes but, indirectly, are likely to affect the industry's sustainability performance. Specifically, these KPIs allow analyzing the social perspective of sustainability.
- *Materials and Packaging* cover all those metrics and indicators about the efficient and effective use of material including: material efficiency, reduction of raw material, increase usage of renewable material and waste reduction.
- *Water and Energy* are the most commonly analyzed resources for assessing environmental performance. It covers energy and water efficiency.
- *Emissions* include the intensity of the weight of all outflows to air, land, and water during a specific period. Its objectives are to minimize emissions to air, land, and water.

Table 5 presents the categorization of sustainability KPIs for SDSCs.

Table 5. Sustainable Key Performance Indicators framework for SDSCs.

Group	KPI	Description
General Aspects	<i>Industrial safety</i>	Indicates numbers of incidents, fatal and nonfatal accidents, health and safety prevention costs.
	<i>Client satisfaction</i>	Measures the level of satisfaction, well-being, and added value to customers and users.
	<i>Employee turnover</i>	Measures the level of turnover in a company, in terms of Number of employee departures divided by the average number of staff members employed.
Materials and Packaging	<i>Usage of raw material</i>	Measures raw material consumption per litre of beverages produced, and non-renewable materials intensity.
	<i>Usage of renewable material</i>	Measures renewable raw material consumption per litre of beverages produced
	<i>Solid waste generation</i>	Grams of solid waste generated per litre of beverages produced
	<i>Recycling of solid waste</i>	Percentage of recycled waste in relation to generated waste
	<i>Product Quality</i>	Measures the number of errors, rejected batches, product defects, costs of bad quality and number of deviations
	<i>Packaging Quality</i>	Measures the quality and safety of packaging

Table 5. Cont.

Group	KPI	Description
<b>Water and Energy</b>	<i>Efficiency in water consumption</i>	Number of litres of water needed to produce one litre of beverage
	<i>Efficiency in energy consumption</i>	Energy used per litre of produced beverage
<b>Emissions</b>	<i>Emission to water</i>	Measures nutrients and organic pollutants and metal emissions
	<i>Emission to land</i>	Measures oil and coolant consumption, restricted substances intensity and metal emissions
	<i>Emission to air</i>	Measures air acidification, dust and particles, transport and greenhouse gases

Figure 7 shows a practical application of the Sustainable Key Performance Indicators for SDSCs. As shown, the attention is focused on the first two phases of the SDSCs because these two factors are the ones involved in the water and packaging practices. Some KPIs, such as emission to air, land, and water; industrial safety; and employee turnover, are applied to the whole supply chain, while water measurements are mainly used to control the syrup production and bottling phase, and finally, packaging and material metrics are adopted for the material consumption monitoring. Furthermore, quality controls are arranged in several strategic points, such as the end of the syrup production, the carbonization processes and the end of the labeling and coding procedures. Additional controls are also scheduled in the distribution phase. Energy consumption is monitored along with the syrup production and bottling processes, as are waste measurement and recycling rates. Figure 7 shows the complete mapping between a generic SDSC and the sustainable KPIs framework for SDSCs.

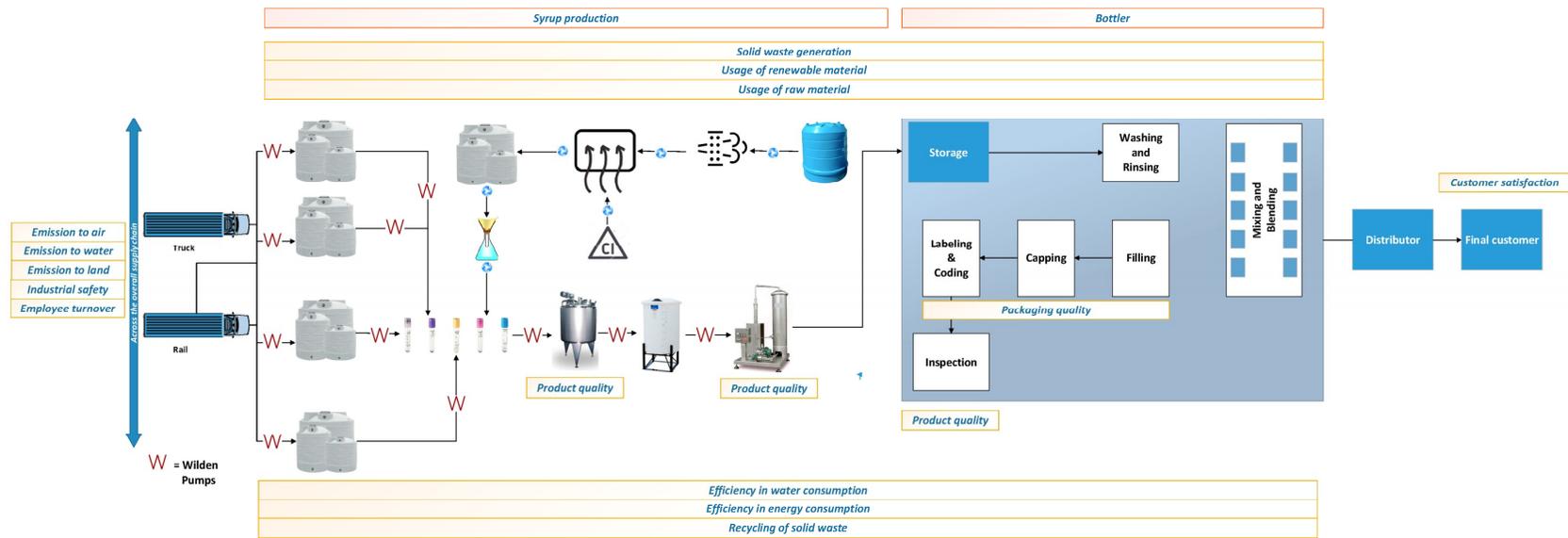


Figure 7. Mapping between a generic SDSC and the Sustainable Key Performance Indicators framework.

## 5. Results

Two case studies were analyzed to find their best practices and KPIs, which were compared with the ones identified in the literature review. At this point, it is important to underline that the proposed case studies are limited to only two companies, which is insufficient to cover all SDSC behaviors, and more case studies might allow for more precise indications.

### 5.1. Case Study A

The first case study concerns a soft drink company, which has four plants and more than 20 production lines. The company covers one-third of the Italian market; it mainly produces and bottles carbonated and non-carbonated drinks, diet drinks and water.

In our research, we focused on this specific company because:

- It is the leader in the Italian market.
- It has a large global market share.
- It seeks continuous improvements.
- It has an excellent record in safety and quality of the products.

The group has stringent controls throughout the supply chain: from the purchasing of raw materials to the production processes, and from the monitoring of products on sale to the development of an effective system of traceability and quality control.

To better adapt to local situations and regulatory constraints, the company has adopted an operating structure divided into three areas: (i) Europe; (ii) America; and (iii) Asia, Africa, and Australia.

With this perspective, the company believes it can accelerate its response to the needs of each market and use all its synergies more widely, reinforcing the group's position in the global market.

The company has two main objectives. The first is to satisfy consumers taste. Quality and nutrition are an absolute must and are always motivated by the desire to create new flavors. Its work in safety, nutrition, environmental sustainability, and people's wellbeing is far-reaching, and this pushes the company to design new business models. The second is to increase revenue while continuing to reduce the impact on the planet and promote healthy drinking habits.

The company's processes have been re-engineered to be as energy efficient as possible while also reducing fossil fuels to a minimum.

The interview with SC Manager allows us to understand the structure of the company, which is composed of four different plants:

Plant 1 produces and bottles carbonated and non-carbonated soft drinks in PET, glass, cans, Pre-Mix and Bag-in-Box.

Plant 2 produces and bottles carbonated and non-carbonated soft drinks in PET, Pre-Mix, and Bag-in-Box.

Plant 3 produces and bottles carbonated and non-carbonated soft drinks in PET, glass, and cans.

Plant 4 produces and bottles water in PET.

Therefore, the two primary objectives of the company with respect to packaging are:

- reduce general waste; and
- minimize the environmental impact of packaging.

The primary objectives of the water, which is used both in producing beverages and preparing bottles for cooling and cleaning equipment, are:

- water efficiency; and
- water treatment and recycling.

The interview conducted with the R&D Manager gave us a better understanding of the packaging components and its features. One hundred percent of the packaging produced (primary and secondary) is recyclable (glass, aluminum, cans, PET, RefPET and Tetra pack).

The design of packaging aims at reducing and recycling materials for the preservation of natural resources. The company considers packaging as one of the main objectives of its environmental management; indeed, it pays close attention both to the design of the packages, and their recyclability.

Thus, the company re-designed bottles to reduce their weight/environmental footprint as follows:

- Type 1 uses 25% recycled PET.
- Type 2 allows 57% saving of PET.
- Type 3 is biodegradable and developed from natural resources (fibers).

Additionally, consumer participation is encouraged by:

- Returnable packaging increases consumers' environmental awareness leading to better product choices.
- Post-consumer actions use bottle and can compacting machines that attract customers by monetary compensation or discounts.

Packaging is considered fundamental to the company; all operations are focused on weight reduction and recovery of packaging and glass recycling. Package recovery and recycling consists of processing, washing and re-inserting the bottles in the production line. Discarded bottles, which do not pass quality control, are sent to the ecological islands of each plant to be recycled.

With respect to the second objective, water, a system of capturing and storing rainwater has been developed, which allows the re-use of water for auxiliary services such as fire protection and sanitary services of the plants.

The company also has cleaning system that reduces energy and water consumption. It is an automatic system, which stores the last rinse water from the cleaning process and reuses it in the first rinse of the following cleaning process. This reduces the water used by 60% and also provides reductions in energy consumption, alkaline detergents and steam, lowering costs.

The company also protects reservoirs in the surrounding area, given the importance they have in facilitating water infiltration. Regarding the evaluation of water management, water levels are monitored daily and compared and adjusted according to the monthly objective. Water consumption is measured by liters of water consumed per liter of manufactured product and each plant has a different requirement as different flavors imply greater sanitation and therefore more water consumption.

Figure 8 shows the wastewater treatment adopted by the company. This water is generally sold to agriculture suppliers, who use it for irrigation. This is a clear example of industrial symbiosis, earning a value from waste, and at the same time increasing environmental effectiveness [63].

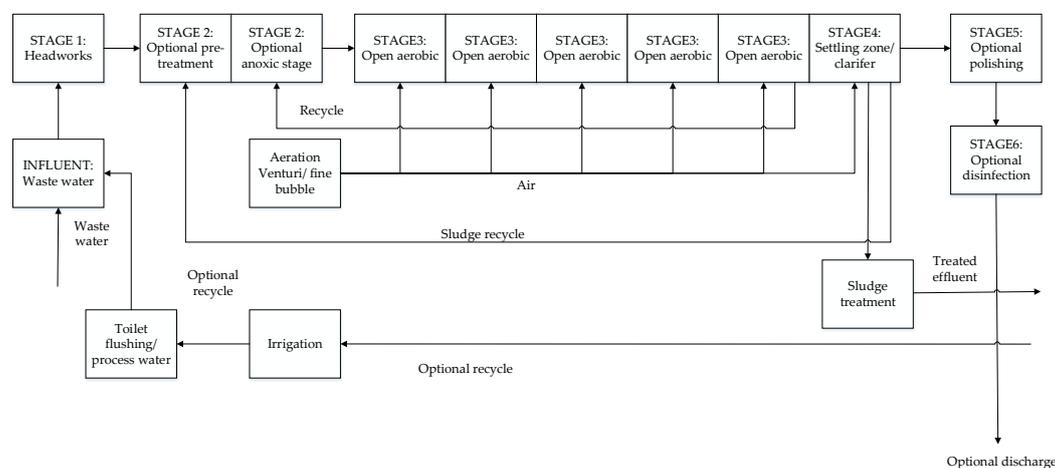


Figure 8. Wastewater treatment.

In summary, the process of water treatment allows the company to:

- reduce water by 60% in the washing processes;
- capture and store rainwater for fire protection and sanitary services of the plants;
- reduce energy consumption and alkaline detergents;
- lower costs; and
- sell wastewater.

Tables 6 and 7 summarize the best practices and KPIs adopted by the company regarding packaging and water. Regarding KPIs, the company monitors nine specific metrics in addition to the company's own KPIs, thus controlling sustainable issues.

**Table 6.** Best practices adopted by the company A.

Packaging Best Practice	Main Results	Water Best Practice	Main Results
Light weighting	Reduction of weight and minimization of impacts on environment	Rainwater recovery	Capturing and storing rainwater for fire protection and sanitary services of the plants
Use of recycled material	25% of each bottle is produced with recycled PET; policies of packaging and glass recycling	Innovative technologies for cleaning processes	60% reduction of water in the washing processes
Design of "Bio-Plastic Bottle"	Reduction of carbon footprint thanks to the adoption of natural and sustainable materials	Recycle and treatment of wastewater	Value added by selling to agriculture producers
Post-consumer actions	Development of special machines, which compact PET bottles and aluminum cans	Protection of reservoirs	Facilitating water infiltration and protecting natural reservoirs

**Table 7.** KPIs adopted by the company A.

KPIs
Client satisfaction
Energy consumption
Favorable internal environment
Industrial safety
Packaging quality
Product quality
Raw material consumption
Recycling of solid waste
Solid waste generation
Water consumption

## 5.2. Case Study B

The second case study concerns a bottling company. It bottles different products such as fruit juice and carbonated drinks; however, in this case, attention was focused only on the process of bottling water. The Italian company is a leader in the water bottling industry; it has four main brands and operates all over the world.

In our research, we focus on this specific company because:

- It is a leader in the water bottling process in Italy.
- It pays great attention to safety and quality of the products.
- It is customer orientated.

Packaging is a critical aspect of the company, representing a huge part of the waste production.

The company is focused on delivering sustainable long-term growth while leaving a positive impact on society and the environment. The goal is to re-think its product portfolio, making beverages more sustainable.

The SC Manager describes the structure of the company, which is composed of seven different plants, which are placed near wells or water springs, all over Italy. The bottling process is very important so the following steps must be followed in this order to prevent contamination:

- (1) Blowing the preform for the PET bottle
- (2) Bottling
- (3) Corking
- (4) Labeling
- (5) Packaging
- (6) Storing

To reduce the environmental impact, the company takes issues of design, analysis and process of packaging very seriously. The main material used for packaging bottled water is PET, which is 100% recyclable. These common practices are adopted:

- Light weighting reduces the package weight by using less PET; this process is done for the primary, secondary and tertiary packaging.
- Design of bio-plastic bottles uses PET produced from sustainable renewable materials, in this case sugar cane.
- Recycled PET is used.
- Post-consumer actions are based on special events or alliances, to sensitize consumers.

It is important to clarify that the lightening process is carried out under methodical test procedures to ensure that the quality and function of the packaging are not altered in the process.

The company is a leader in the PET recycling process in Italy. PET recycling reduces consumption of raw materials, production impact and waste. Every year, the company has the possibility to reduce bottle weight on certain production lines leading to a substantial saving of resin per year.

The latest labeling process includes nutritional information to help consumers make informative choices on products.

The packing strategy is based on:

- expanding the use of returnable bottles;
- raw material reduction;
- recycling of raw materials; and
- reverse logistics and consumer education.

The recovery of bottles is one of the biggest challenges to waste management. The value chain and consumer awareness and participation are key. For non-returnable products, the strengthening of existing recovery chains in the different communities is fundamental, which leads to the development of public–private partnerships. The company is working closely with its suppliers: (i) to reduce the consumption of non-renewable resources used in primary and secondary packaging; and (ii) to develop agreements with industrial scrap recyclers to improve the competitiveness of recycled resin.

In summary, the process of PET recycling allows the company to:

- reduce greenhouse gas emissions by 19% per liter of water produced;
- reduce greenhouse gas emissions by 30% on the packaging phase; and
- reduce non-renewable energies by 8%.

One of the main goals of the company is to defend water for the next generations by protecting water sources and the ecosystem. Water sustainability signifies customer wellness, water quality enhancement and environmental impact reduction. The water used to clean bottles is extracted from the sea and goes through a desalination process with no impact on the environment. In the event of a failure or excessive consumption, there is also a backup system which uses mountain

water. The production plant contributes to the promotion of a culture of good use of water educating consumers to the fact that water is a scarce good. These policies linked to water sustainability are mainly viewed from the social perspective, which focuses on:

- water source protection;
- responsibility for water production;
- enhancement of local communities;
- educational activities conducted to make people aware of their responsibilities and the importance of water; and
- educational activities with respect to the importance of hydration for health.

Tables 8 and 9 summaries the best practices and KPIs adopted by the company regarding packaging and water.

**Table 8.** Best practices adopted by the company B.

Packaging Best Practice	Main Results	Water Best Practice	Main Results
Light weighting	16% weight reduction	Educational activities	These are conducted to make people aware of: (i) the responsibilities of the importance of water; and (ii) the importance of hydration.
Use of recycled material	PET recycled, which allows reduce CO <sub>2</sub> emissions, greenhouse gas and non-renewable energy consumption		
Design of Bio-Plastic bottles	PET production from sugar cane, which allows the reduction of raw material consumption		
Post-consumer actions	Special events or alliances to sensitize consumers		

**Table 9.** KPIs adopted by the company B.

KPIs
Client satisfaction
Employee turnover
Energy consumption
Packaging quality
Product quality
Raw material consumption
Raw material consumption
Renewable material consumption
Water consumption

Regarding KPIs, the company monitors six specific metrics in addition to the company own key performance indicators with the aim to control sustainable issues.

### 5.3. Comparison between Literature Data Analysis and Case Studies

In this section, a comparison between the best practices and KPIs selected through the literature review and the two proposed case studies is presented. Concerning packaging, the case studies show there is a harmony between literature and real implementation. Indeed, the best practices derived from the literature review find an application in the industrial reality. Specifically, lightweight, using recycled material and design of “plant bottle” are the most employed, while the upcycling practice and adoption of more efficient technologies are not implemented. It is also important to underline that both companies adopt “post-consumer actions” such as special events or alliances to sensitize consumers. This best practice was not detected through the literature review.

With respect to water, we can notice a partial application of selected activities. While the first case study shows a good inclination to water issues, the second case study treats it with a more social

perspective, mainly adopting actions for sensitizing consumers. Tables 10 and 11 show the comparison between the two proposed case studies and the comparison with the literature with respect to best practices selection, respectively.

**Table 10.** Comparison between the best practices selected through the literature and the application in the proposed case studies (Packaging).

Best Practice	Case Study A	Case Study B
Light weighting	X	X
Use of recycled material	X	X
Upcycling		
Design of “Plant bottle”	X	X
Adoption of more efficient technologies		
Evolution of collection models	X	X

**Table 11.** Comparison of the best practices selected through the literature and the application in the proposed case studies (Water).

Best Practice	Case Study A	Case Study B
Reduction	X	X
Recycling and treatment of wastewater	X	
Rainwater recovery	X	
Innovative technologies for cleaning processes	X	
Engagement with suppliers, especially those in agriculture	X	

Finally concerning KPIs, measuring the sustainability of a process implies the identification of issues and potentials, and support the visualization of benefits from improvement measures [64]. The development and application of sustainable indicators depend on the purpose for which they will be applied. The comparison between the literature analysis and case studies establishes that current approaches to measure, control and improve sustainability in manufacturing processes have shortcomings in addressing industrial needs in a comprehensive and suitable manner. The adoption of standardization and a clear framework industry specific can be significant enablers for supporting the measurement, control and improvement of sustainability in SDSCs. Table 12 shows that there is a partial application of the selected KPIs, particularly there is a shortage in adopting specific metrics to measure emissions, while both companies embrace metrics such as “client satisfaction”, “use of raw material”, “product quality”, “packaging quality”, “efficiency in water consumption” and “efficiency in energy consumption”.

**Table 12.** Comparison between KPIs selected through the literature and the application in the proposed case studies.

KPIs	Case Study A	Case Study B
Industrial safety	X	
Client satisfaction	X	X
Employee turnover		X
Use of raw material	X	X
Use of renewable material		X
Solid waste generation	X	
Recycling of solid waste	X	
Product Quality	X	X
Packaging Quality	X	X
Efficiency in water consumption	X	X

Table 12. Cont.

KPIs	Case Study A	Case Study B
Efficiency in energy consumption	X	X
Emission to water		
Emission to land		
Emission to air		

SDSCs demonstrated support for the promotion of energy efficiency as an important driver for the industrial competitiveness, while reducing emissions to air, land and water represents a missing area. SDSCs are characterized by relatively low energy intensity compared with many other industrial sectors, where sharply rising energy prices have become a notable cost factor. Enhancing the utilization of low-carbon electricity in the SDSCs has significant potential to reduce not only greenhouse gas emissions but also air, land and water pollution created from the mining and burning of fossil fuels. Thus, we conclude that emission to water, air, and land are not directly measured but are indirectly considered in other KPIs such as efficiency in energy consumption and recycling of solid waste.

## 6. Conclusions

This paper investigated SDSCs, with a particular focus on their production processes, best practices and KPIs with respect to sustainability dimension. Literature review and case study were used as a mixed research methodology to define sustainable best practices and KPIs.

First, a literature review was performed to understand the level of intersect between sustainability and SDSCs. It emerged that sustainability is a prime objective of SDSCs; indeed, it is the most analyzed trend. The literature review allowed us also to identify which phases of the production process require more attention and then define the principle recurring activities for water and packaging.

A framework based on the literature review was developed to define sustainable best practices and KPIs for the soft drink sector. Then, it was evaluated through two case studies. Concerning packaging, the case studies point out an agreement between literature and real implementation. Indeed, the best practices derived from the literature review find application in the industrial reality. With respect to the water concept, we can notice a partial application of selected activities. While the first case study shows a good inclination to water issues, the second case study treats it with a more social perspective, mainly adopting actions for sensitizing consumers. Finally, concerning KPIs, the comparison between the literature analysis and case studies establishes that current approaches to measure, control and improve sustainability in manufacturing processes have shortcomings in addressing industrial needs in a comprehensive and suitable manner.

Although interesting results were found in this study, the authors are aware of some restrictions. The limitations of this study are: (i) The proposed case studies are limited to only two companies, which are insufficient to cover all SDSC behaviors, and more case studies might give more precise directions. (ii) This study is limited to the soft drink context while an analysis of the whole beverage sector could be useful to understand if additional best practices can be found and help companies in a better management of water and packaging issues. (iii) The study focused on water and packaging while other consistent activities need investigation. (iv) Due to the predominant attention to water and packaging, there is a resulting focus on the first two phases of SDSC.

The recommendation for future research are: (i) validate the results of this study with additional case studies to give clear directions; (ii) extend the research boundaries of the study; and (iii) analyze the whole supply chain to find additional critical points and related best practices.

Finally, the results reported in this paper could be potentially used as a starting point for researchers and practitioners with the aim of guiding SDSCs through sustainable progress and improvements.

**Author Contributions:** M.D., C.P., B.A., F.T. and S.T. conceived and design the framework for the study; M.D. and C.P. organized the interviews with companies gathering the data for the study and wrote the paper.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

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