Chapter 18
Sustainable Food Supply Chain Design

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18.1 Introduction

Supply Chain Management (SCM) has become part of the c-management agenda in Western countries since the 1990s, particularly in the manufacturing and retail industries (Chopra and Meindl 2012). More recently, interest in SCM has also been growing in the agrifood industry, both in developed and developing countries. Executives of agrifood companies are aware that successful coordination, integration, and management of key business processes in the supply chain will determine their competitive success. Sustainable Food Supply Chain Management (SFSCM) refers to all forward processes in the food chain, like procurement of materials, production and distribution, as well as the reverse processes to collect and process returned used or unused products and/or parts of products in order to ensure a *socioeconomically* and *ecologically* sustainable recovery (Bloemhof and van Nunen 2008).

Companies—and supply chains—nowadays have to obtain a "license to produce and deliver", that is, society has to accept the way they produce and deliver their goods (Bloemhof and van der Vorst 2015). If this is done by using questionable methods (think of child labor, environmental pollution, and so on), their products become less acceptable. Western-European consumers have become more demanding on food attributes such as quality, integrity, safety, diversity, and sustainability

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(Van der Vorst et al. 2009). Global consumption of food has significantly increased due to population growth, alterations in overall nutritional needs and rising economic incomes. This increased consumption has increased the demand for production and distribution of food worldwide leading to severe global economic, social, and environmental problems (Tilman et al. 2002). The Food and Agriculture Organization of the United Nations (FAO) states that food sectors have to increase their production and decrease the negative impact of production and distribution simultaneously (FAO 2012).

This chapter discusses the design of sustainable food supply chains. In Sect. 18.1, we discuss the key questions related to the concept of a Sustainable Food Supply Chain, which have to do with (1) the typicality of food supply chains, (2) the issue on how to measure sustainability and (3) the impact of food supply chains to improve sustainability. In Sect. 18.2, we provide a brief literature review on these issues, whereas Sect. 18.3 discusses the trends related to these questions, showing future needs in the field of sustainable food supply chains (puzzles that researchers and practitioners need to work on).

18.2 What Is a Sustainable Food Supply Chain Design?

In this section, we discuss the following key questions:

1. What makes food supply chains different from other supply chains when it comes to sustainability?
2. What are the key performance indicators for sustainability in food supply chains?
3. How to redesign food supply chains to improve sustainability?

18.2.1 What Makes Food Supply Chains Different Than Other Supply Chains When It Comes to Sustainability?

Food supply chains consist of organizations that produce and distribute vegetable or animal-based products to consume. Nowadays, Western-European consumers have become more aware of the origin and nutritional value of their food and expect food in retail stores to be of good quality, to have a decent shelf life and to be fit for purpose (Smith and Sparks 2004). Consumers' requirements especially refer to product availability, product quality, and an acceptable price. These requirements need to be taken into account when (re-)designing Food Supply Chains, next to traditional efficiency and responsiveness requirements (Soysal et al. 2012).

A number of recent trends such as globalization, urbanization and agro-industrialization make the organization of agrifood chains and networks more complex, as these networks are rapidly moving towards globally interconnected systems with a large variety of relationships. This is also affecting the ways in which food is produced, processed and delivered at the market. Perishable food products can nowadays be shipped from halfway around the world at fairly competitive prices. Demand and supply are no longer restricted to nations or regions but have also become international processes. The market exerts a dual pressure on agrifood chains, forcing improved coordination among buyers and sellers and continuous innovation.

Food Supply Chains are different from other product supply chains. The fundamental difference is the continuous and significant change in the quality of food products throughout the entire supply chain until the point of final consumption. Investments in network design should be aimed at both improving logistic performance and at the preservation of food quality.

A Food Supply Chain comprises organizations responsible for the production and distribution of vegetable or animal-based products. These products can be fresh (such as vegetables, flowers, fruit) or processed (such as portioned meats, snacks, desserts, canned food products). In general, these chains may comprise growers, auctions, wholesalers, importers and exporters, retailers and specialty shops and their input and service suppliers. In fresh supply chains, the main processes are the handling, conditioned storing, packing, transportation, and especially trading of goods. Basically, all these supply chain steps leave the intrinsic characteristics of the product grown or produced in the countryside untouched. In processed food supply chains, agricultural products are used as raw materials for producing consumer products with higher added value. In most cases, conservation and conditioning processes extend the shelf life of the agricultural and consumer products.

18.2.2 What Are the Key Performance Indicators for Sustainability in Food Supply Chains?

Traditional performance indicators such as costs, throughput time or technical quality of products are insufficient to find the best sustainable configuration of the supply chain. To help decision makers to assess the sustainability of their supply chain design, a comprehensive assessment regarding the Triple Bottom Line (TBL) performance is needed. This TBL concept was first used by Elkington (2004) and relates to a simultaneous consideration and balance of economic, environmental, and social goals from a business point of view (also known as the Triple P philosophy of People, Planet, and Profit).

Performance measurement tools estimate sustainability throughout indicators. Sustainability indicators are an essential part of the process of assessment, benchmarking, and decision making. Indicators play an important role in sustainability assessment to value the current situation. Moreover, indicators help to benchmark the current sustainability performance with that of competitive companies or the required performance to obtain membership in a certificate scheme (such as Lean and Green) or the performance required by legislation. Indicators also support performance evaluation of management policies and improvement practices. Indicators make visible every change in the social, economic, and environmental dimensions of sustainability.

Within the context of Food Supply Chains, the sustainability discussion focuses on the reduction of product waste (products not used for human consumption because the quality is not suitable anymore), number of miles a product has travelled before it reaches the customer's plate (Food Miles) and all greenhouse gas emissions related to the business processes in the supply chain network (Carbon Footprint, see also Chap. 3 by Boukherroub et al. (2017)).

18.2.3 How to Improve Sustainability in Food Supply Chain Design?

Van Gogh et al. (2013) show that about 40 % of food waste relates to supply chain activities. The top four of the causes of this spoilage are related to the cold chain storage (conditioned transport and storage of perishable products), handling and packaging. Also the Food and Agricultural Organization acknowledges that substantial food loss takes place in the supply chain, during postharvesting, processing, and distribution (Fig. 18.1).

Sustainability of supply chains does imply improvements of a combination of different and sometimes conflicting factors. How to combine economic, social, and environmental indicators? Literature on performance indicators for sustainable logistics shows no consensus. Some authors describe indicators as separate entities, whereas others acknowledge that factors related to sustainable logistics can influence more than one dimension and create several impacts. This change evokes the need for an integrated approach that links food supply chain network decisions to the three dimensions of sustainability (economic, environmental, and social).

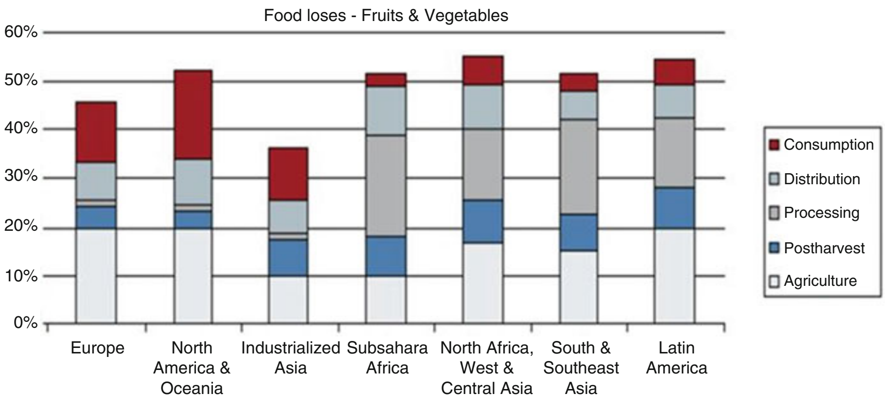

Fig. 18.1 Food losses in the chains of fruits and vegetables (FAO 2013)

Sustainability in itself is not a new research area, but the implication of sustainability in food supply chain networks is quite new. Food Supply Chain Networks are complex, comprising a wide diversity of products with different characteristics and quality requirements, dynamic interactions, and markets (Soysal et al. 2012).

18.3 State-of-the-Art in Sustainable Food Supply Chain Design

This section describes the state-of-the-art in Sustainable Food Supply Chain Design. First, the literature on Food Supply Chain is discussed; resulting in lessons learned why food logistics is not easy. Second, the latest state-of-the-art on sustainability performance assessment is shown, followed by a literature review of papers discussing quantitative models for sustainable food logistics management.

18.3.1 Lessons on Food Supply Chains

Bourlakis and Weightman (2004) discuss a list of specific process and product characteristics of Food Supply Chain Networks that impact the (re)design process for an FSCN, including the following:

- Seasonality in production, requiring global sourcing.
- Variable process yields in quantity and quality due to biological variations, seasonality, and random factors connected with weather, pests, and other biological hazards.
- Keeping quality constraints for raw materials, intermediates and finished products, and quality decay while products pass through the supply chain. As a result there is a chance of product shrinkage and stock-outs in retail outlets when product's best-before-dates have passed and/or product quality level has declined too much.
- Requirement for conditioned transportation and storage means (e.g., cooling).
- Necessity for lot traceability of work in process due to quality and environmental requirements and product responsibility.

Due to these specific characteristics of food products, the partnership thoughts of SCM in FSCs have already received much attention over the past years. These characteristics have an impact on the supply chain design process (see a.o. Lutke Entrup 2006):

– In the overall supply chain, it is important to include shelf life constraints for products and changes in product quality level while a product is progressing through the supply chain (e.g., quality decay or ripening).

- In the supply part of the supply chain, agrifood industries need to contract suppliers that can guarantee the supply of raw materials in the right volume, with the right quality at the right place and time. Agrifood supply has long production throughput times (harvesting only 1 or few times a year), there is seasonality in the production, and quality and quantity have a high variability.
- Apart from the suppliers, also the logistic service providers (LSPs) play an important role as the quality of food products depends heavily on the conditions in all steps of the supply chain. For example, exposing products like fresh milk or meat to high temperatures for sometime will significantly reduce the shelf life of these products. The same is true for disturbances in the supply chain that result in long waiting times at customs or in the airports or harbors. Especially for products with a small shelf life (fresh tropical fruits), disturbances cause a significant percentage of food spoilage.
- For the food industry, process yields are variable in quantity and quality. Alternative process routes and recipes exist for producing the same product. Cleaning and processing times are product-dependent and lot traceability is very important.
- Supply chain coordination is essential to take appropriate decisions on conditioned transport. For retailers, the seasonal supply of products requires often global sourcing.

18.3.2 Lessons on Sustainability Key Performance Indicators for Food Chains

In 1992, in the context of the Rio Declaration on Environment and Development, the Earth Summit recognized in chapter 40 of its proceedings called Agenda 21, the urge for clear and universal metrics of sustainable development. In the opinion of the committee, the need for reliable and pertinent indicators that are able to guide the shift towards sustainability arises from the incapability of current measurement systems to evaluate this aspect. The new standards are required to illustrate both policy makers and the general public the linkages and trade-offs between economic, environmental, and social values as well as to evaluate and monitor the long-term implications of current decisions and behaviors, from the double-edged perspective of institutions and businesses.

According to the FAO report in 2012, more than one hundred countries have established national strategies for sustainable development, including sustainability targets and indicators. In spite of the abundant attempts for making food and agriculture sectors sustainable, no internationally accepted standard defines what “sustainable food production” essentially requires (FAO 2012). “Neither a commonly accepted set of indicators that have to be taken into account when measuring sustainability performance, nor widely accepted definitions of the minimum requirements that would allow a company to qualify as ‘sustainable,’ exist” (FAO 2012: 9).

Table 18.1 Sustainability indicators for food chains

Environmental indicators	Social Indicators	Economic indicators
SAFA Sustainability indicators for food chains (FAO 2012)		
Energy efficiency	Human rights	Profitability
Climate change (GHG emissions)	Equity	Vulnerability
Emission of air pollutants	Occupational health and safety	Local economy
Water quantity	Food and nutrition security	Decent livelihood
Land use	Product quality	Resilience to Economic
Soil degradation		Risk
Material cycle		
Waste (weight and volume)		
Biodiversity		
Animal welfare		
Sustainability indicators for food logistics (Baldwin 2009)		
Food miles	Ethical transport	Percent of food lost in mishandling
Environmental monitoring system	Health and safety incidents	Type of distribution
Hazard substance exposure	Distance between grower and distributor	Retail access
Environmental reporting	Profit between farmer, processor, retailer	Labor productivity
	Quality of life and working satisfaction	Diversity of market
	Average wage	Transport efficiency
		Imported vs. domestic products

The FAO developed the guidelines for Sustainability Assessment of Food and Agriculture systems (SAFA). SAFA suggest a comprehensive list of sustainability indicators in different categories including both qualitative and quantitative indicators. These indicators relate mainly to production processes at farm level. Baldwin (2009) evaluates the sustainability indicators especially in the logistic part of food chains. Table 18.1 summarizes these indicators, where the first block relates more to production processes and the second block to the logistics processes.

The supply chain processes (e.g., transport and storage) have a significant impact on global warming because food is often shipped long distances. Although the impact of transportation is important, lifecycle analyses (LCAs) indicate that for most foods, transportation does not have the largest environmental impact (see Chap. 2, Guinée and Heijungs (2017) for more on LCA). However, as many options are available for delivering food to consumers, these supply chain configurations have vastly differing energy and emissions profiles, and therefore evaluating trade-offs and opportunities is necessary for a significant improvement in sustainability for food supply chains (Wakeland et al. 2012).

The UK Sustainable Development Commission formulates the following characteristics referred to the sustainable supply chains: safe and healthy production support the existence of the rural communities, elimination of the overusage of natural resources, reaching high environmental performance throughout less consumption of energy and of resource inputs as well as throughout exploiting more renewable energy. Providing safe and hygienic working environment for the employees, establishing high standards of animal health and welfare, sustaining the level of available resources for meeting the needs of the society are also part of the characteristics of the sustainable supply chains.

The main hotspots that relate to sustainability are the impact on energy (emissions, carbon footprint) and materials (spoilage and waste). Researchers have proposed mathematical optimization models to (re-)design the Food Supply Chain taking into account the aforementioned sustainability KPIs. The following part presents a review of these models.

18.3.2.1 Lessons on Sustainable Food Supply Chain Design Models

Food supply chain network design coordinates a variety of activities such as transportation, inventory management, facility location, or production planning. These activities require several decisions to be made, which can be related to strategic (e.g., determining location and sizes of facilities in a supply chain), tactical (e.g., determining inventory replenishment times) and operational (e.g., determining resulting routes to deliver products to the final destinations) levels of planning and execution. Food supply chain network design, therefore, determines the structure of a food chain and has the potential to affect supply chain KPIs such as cost and responsiveness.

While managing the supply chain activities, sustainable food supply chain network design takes environmental and social externalities of operations into account besides traditional cost concerns. The introduced indicators in the previous subsections are used to assess the performance of a supply chain in terms of managing these externalities.

Operations Research literature presents various decision support tools to better manage (sustainable) food supply chain network design problems. We conducted a literature review on quantitative studies to analyze the currently available quantitative models and point out modelling challenges in sustainable food supply chain network design problems. Literature search is carried out within well-known databases, Thomson Reuters (formerly ISI) Web of Knowledge, Google Scholar, EBSCO, and followed by reference and citation analyses to find related contributions. The following search criteria are employed: food supply chain distribution planning, food supply chain quantitative models, food supply chain network design, sustainable food supply chains, network design for perishable products, location and allocation models, and green network design.

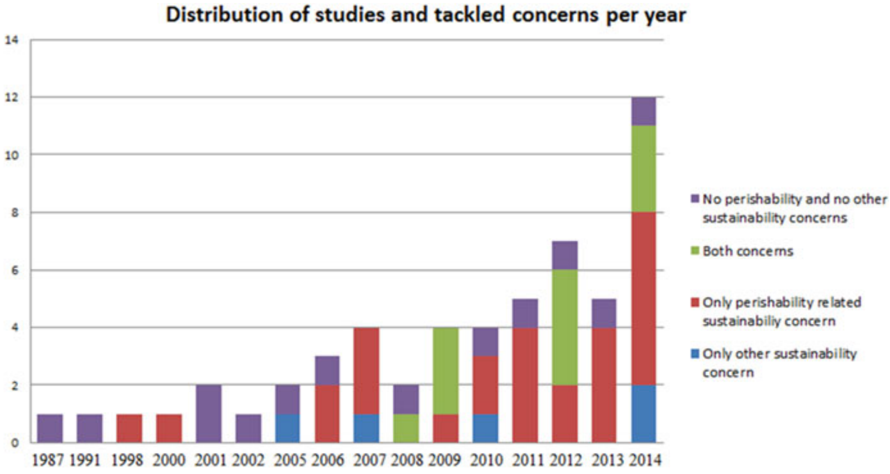

Fig. 18.2 Distribution of food supply chain studies in literature

Analyzing the used indicators, we observe that perishability-related sustainability concerns such as food waste and quality decay have received more attention than other sustainability concerns such as emissions and energy use.

Figure 18.2 shows the distribution of 55 studies between 1987 and 2014. We consider four groups in the literature on food supply chains: (1) no perishability and no other sustainability issues taken into account, (2) both concerns: perishability and at least one other sustainability concern have been taken into account (i.e., emissions, water, accrued jobs), (3) Only perishability-related sustainability concern has been considered, and (4) Only other sustainability concern: has at least one other sustainability concern which is not directly related with perishability. Note that all of these groups have cost or profit concerns, which relate to the economic dimension of sustainability.

The reviewed studies along with regarded sustainability aspects in food supply chain network design models are presented in Table 18.2. According to the results, the number of studies on food supply chain network design has been increasing in the last years. Moreover, incorporating perishability-related sustainability concerns and the other sustainability considerations into the developed food supply chain network design models is becoming trendy. The main reasons for the increased interest to the sustainability are (1) pressures from various stakeholders such as customers and nongovernmental organizations, (2) global competition and economic concerns, and (3) legislation.

The review of the literature shows that most studies assume that products have fixed shelf lives and deteriorate based on time (e.g., Ekşioğlu and Jin 2006; Soysal et al. 2014; Ahuja et al. 2007). In these studies, product quality decays occur either in a linear way (e.g., Ahumada and Villalobos 2009) or in other ways such as exponential (e.g., Blackburn and Scudder 2009). While managing product perishability, some

Table 18.2 Literature review on sustainability aspects in food supply chain network models

#	Studies	Sustainability concerns not related to perishability	Perishability-related sustainability concern
1	Van der Vorst et al. (1998)		√
2	Van der Vorst et al. (2000)		√
3	Apaiah and Hendrix (2005)	√	
4	Kanchanasuntorn and Techanitisawad (2006)		√
5	Ekşioğlu and Jin (2006)		√
6	Gong et al. (2007)		√
7	Ahuja et al. (2007)		√
8	Bilgen and Ozkarahan (2007)	√	
9	Zanoni and Zavanella (2007)		√
10	Dabbene et al. (2008)	√	√
11	Akkerman et al. (2009)	√	√
12	Van der Vorst et al. (2009)	√	√
13	Ahumada and Villalobos (2009)	√	√
14	Blackburn and Scudder (2009)		√
15	Oglethorpe (2010)	√	
16	Rong and Grunow (2010)		√
17	Wang et al. (2010)		√
18	Hsu and Liu (2011)		√
19	Ahumada and Villalobos (2011)	√	√
20	Bosona and Gebresenbet (2011)		√
21	Yan et al. (2011)		√
22	Hasani et al. (2012)		√
23	Rong et al. (2011)		√
24	Zanoni and Zavanella (2012)	√	√
25	Amorim et al. (2012)	√	√
26	Ahumada et al. (2012)	√	√
27	You et al. (2012)	√	√
28	Yu and Nagurney (2013)		√
29	Tsao (2013)		√
30	Piramuthu et al. (2013)		√
31	Grunow and Piramuthu (2013)		√
32	Khalili-Damghani et al. (2014)		√
33	Soysal et al. (2014)	√	√
34	Validi et al. (2014)	√	
35	Pan et al. (2014)	√	
36	Firoozi et al. (2014)		√
37	Chen et al. (2014)		√
38	Kim et al. (2014)		√
39	Seyedhosseini and Ghoreyshi (2014)		√
40	Meneghetti and Monti (2015)	√	√
41	Linnemann et al. (2014)	√	√
42	Liu et al. (2014)		√

studies take also other parameters into account such as temperature, enthalpy, and color through specific quality decay models (e.g., Linnemann et al. 2014; Ahumada et al. 2012; Gong et al. 2007).

Another finding is that the developed models do not always allow product wastes. In some cases, products have to be used within the limited time period and waste cannot occur (e.g., Soysal et al. 2014; Seyedhosseini and Ghoreyshi 2014). In other cases, it is not always possible to use products before they are spoiled (e.g., Wang et al. 2010).

Lastly, some researchers do not focus on quality decay during only storage, but also have addressed temperature tracking during transportation through temperature-controlled trucks or multi-temperature logistics (e.g., Bosona and Gebresenbet 2011; Hsu and Liu 2011).

Regarding sustainability indicators which are not related to perishability, it has been observed from the literature that energy use and emissions are the most acknowledged indicators in the reviewed models (e.g., Validi et al. 2014; Van der Vorst et al. 2009; Pan et al. 2014). The other issues addressed in the studies are the following: nutritional content of products (e.g., Oglethorpe 2010), water use (e.g., Ahumada and Villalobos 2009), number of accrued jobs (e.g., Ahumada et al. 2012), and energy levels of operations (e.g., Linnemann et al. 2014).

As discussed above, researchers rely on several assumptions while managing sustainability in food supply chain network design problems. These assumptions obviously affect the developed decision support models and therefore the resultant food supply chain network design plans. Concluding, while modelling sustainable food supply designs, the following issues have to be taken into account:

1. The main factors affecting **shelf life of products** have to be determined. Food science literature can be consulted to have a better insight in the perishability nature of food products. If a specific quality decay model exists for the studied problem, this model or its simplification can be employed to tackle with the perishability of the product. The existing models can be too complex to simplify or they may require many parameters which are difficult to obtain. Otherwise, generic models which are proposed for food products can be used. For instance, the generic model used in Rong et al. (2011) to estimate product shelf life could be an option. The model is dependent on various parameters such as storage time, temperature, activation energy, etc.
2. **Product waste risk** should not be ignored in food supply chain network design problems. Due to several reasons such as service level requirements and demand uncertainty, it could be inevitable to have zero product waste. As shown in Soysal et al. (2015), the ignorance of product perishability in a quantitative model for a special supply chain problem might lead to higher product wastes, infeasible solutions, and unsatisfied service level targets. Therefore, decision support models for food supply chain problems should take potential product waste into account.
3. Product quality decays do not occur only during storage. Products start to deteriorate even before they are completely produced or ready for the consumption.

This fact requires tracking product quality throughout the whole chain starting from production to the point of consumption. The interested reader is referred to the study of van der Vorst et al. (2011). They claim that a **quality controlled chain** could bring the benefits of higher product availability, constant quality, and less product losses by the help of controlling goods in a proactive manner and having better established supply chain designs.

4. Most of the sustainability indicators for food supply chains introduced in Table 18.1 have not been incorporated in food supply chain network design models. However, social awareness on these sustainability indicators has been growing in practice. It might be thus expected that future OR models can comprise an **extended set of sustainability indicators** to better aid decision makers in sustainable food supply chain management.
5. Researchers often use simple models or approaches to estimate sustainability indicators, which results in rough calculations of e.g., water consumption or energy use. More interdisciplinary research is required to advance our understanding of sustainability-related KPIs. Quantitative approaches which are proposed in other research fields to estimate performance of sustainability indicators can be incorporated into the decision support models in Operations Research.
6. Most studies put boundaries to the sustainability considerations, i.e., taking energy use from transportation into account but ignoring energy used for stocking, which restricts the assessment of environmental or social impacts associated with all the stages of a product's life. These limited views can affect the trade-off relationships among KPIs and therefore the resulting plans in network management. Lifecycle Analysis (LCA) models can be combined with OR models to better estimate the externalities of products from cradle-to-grave (see also Chap. 2 by Guinée and Heijungs (2017)).

To conclude: the research on food supply chain network design is still developing considering the extension of the traditional approaches through taking environmental and social considerations of the supply chain operations into account. These enhanced models can better capture current food supply chain dynamics and improve food quality and safety, availability of food, and create sustainable and efficient business networks, which are the main issues faced by stakeholders in food supply chains (Soysal et al. 2012).

18.4 Practical Implications: Trends in Sustainable Food Supply Chains

Here, we discuss the impact of trends in the coming years on the agrifood sector. We discuss the impact of urbanization and the upcoming of sustainable modalities. Further, we discuss the development of Sustainability Dashboards.

18.4.1 Impact of Urbanization

First, the demographic developments are such that more people live on the planet, but less people live in Western-Europe. More people live in urban areas in an individualized society. In 2015, already 60 % of the world population lives in cities. This results in an increase of demand for meat, fish, and dairy, while the employment rate for farming activities in the countryside drops. The carbon footprint of meat and fish is on average much higher than that of vegetables and grains. Therefore, land, material, and energy use will increase as well as the amount of food spoilage and waste. Secondly, climate change will result in a decrease in the variety of species. Nowadays, only 150 different crops are harvested worldwide resulting in a drop of biodiversity. Only 12 crops are responsible for 75 % of the world food production, making this system very vulnerable. One of the practical implications of sustainability in food supply chains is the shift in production activities. Agrifood production will move to cheap countries, but there will be also a focus on locally produced products (e.g., urban farming).

Urban farming gives an opportunity to operate more independently from global threats related to climate, prices, and political stability. Urban farming can lead to a variety of meaningful social functions. However, urban farming also asks for a new way of short-distance logistics to ensure that processed and unprocessed products are distributed fast and safe to the places in the city where consumers need them. Metropolitan food clusters and logistic lines around the major global cities will provide residents with sufficient food.

As distribution is one of the main sources of food waste and carbon emissions in the food lifecycle, this is another motivation to a shift in food production activities. Geographically local supply chains are considered to be more sustainable due to the encouragement of the rural enterprising and the opposition against the agriculture monopolies (Smith and Sparks 2004).

In the future, we expect a combination of global low-cost agrifood production with local sustainable high-quality agrifood production.

18.4.2 Emission Driven Transportation

At the moment, initiatives start all over the world. In California, USA, sustainable freight pathways to zero and near-zero emissions are explored. Zero-emission drivetrain technologies have been developed for on-road heavy-duty freight vehicles and 100 % solar-powered and wind-powered cargo ships make their way through the seas (e.g., the Turanor Planet Solar, Eco Marine Power, Green Marine, and the Dutch Ecoliners). Low Emission Zones in cities (such as London) do not allow entrance to vehicles that do not satisfy the emission requirements. Electric vehicles could be a solution for entering these zones, but requires extra handling at the borders of the city (Blanco and Sheffi (2017) discuss green logistics in greater detail in Chap. 7).

18.4.2.1 Sustainability Dashboards

Sustainability assessment aims to facilitate the decision making process related to actions which are needed to provide sustainability in short-term or long-term perspective for global or local systems. At the moment, most Business Dashboards focus only on numerical economic results and do not take into account the numerical visualization of social and environmental indicators.

One tool for visualizing sustainability results is the Dashboard of Sustainability. The Dashboard of Sustainability is elaborated by the Consultative Group on Sustainable Development Indices and the Joint Research Centre. It dates from the end of the 1990 and measures the economic, social, and environmental dimensions of sustainability. The Sustainability Dashboard allows comparing different scenarios taking into account the economic, social, and institutional trends. The information which needs to be measured is organized in three levels:

1. Individual indicators for sustainability evaluation
2. Synthetic indexes which integrate multiple indicators into one single indicator (Environment, Economy, Society)
3. Index of overall sustainability (Sustainability Development Index or Policy Performance Index) which averages the synthetic indexes

The information is presented in a numerical and graphical way. The individual indicators are assigned to segments. The achievements of the indicators for all different contexts are revealed by the color of the segment. Usually the color varies from dark green (excellent) to dark red (very bad).

Bloemhof et al. (2015) collected primary and secondary data on sustainability KPIs from food and logistics companies in the Netherlands. Results show that energy and water use as well as emissions have most attention from food industry; carbon footprints are central to LSPs (Chapter 4 by Hoekstra (2017) focuses on water footprinting).

18.5 Future Needs

For a more sustainable food supply chain, a redesign of the food supply chain network is necessary. To meet the future challenges on sustainability and efficiency, biomass materials must be converted into valuable products. Future food supply chains are not only challenged to increase productivity, but also to supply energy and other biobased products without compromising on resources availability and resource efficiency. This requires a biobased circular economy, i.e., encompassing the sustainable production of biomass and its conversion into food, feed, biobased materials, and bioenergy. So far, optimization models have only been used to find the optimal route for the production of food products or biofuels (Zondervan et al. 2011). This needs to be extended to a multiproduct optimization to create food, feed, fuel, chemicals, and materials from biomass.

Research will be necessary in the field of time-dependent environmental conditions, under which products are (re)packed (e.g., using modified atmosphere packaging), stored, and transported (e.g., using reefer containers), in order to improve on food quality. This will result in longer shelf lives, and therefore, less spoilage. Furthermore, emphasis should be put on redesigning processes in order to reduce greenhouse gas emissions and energy consumption. The transition towards a sustainable food chain is a challenge for the food sector. Future food chains should operate in synergy with environmental, social, and economic aspects leading to the following targets:

1. *Improve resource efficiency and effectiveness in the food chain:* prevent food spoilage and shrinkage, optimal valorization of by-products and waste streams, extending shelf life of food products.
2. *Efficient supply chain networks:* reduction of CO_2 emissions in food logistics reducing transport kilometers improves mobility.
3. *Reduces environmental impact of packaging,* reduces carbon emissions related to plastic packaging materials and improve recycling rates.

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