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End-to-end performance measurement systems for agri-food supply chains

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1 Introduction

Measuring supply chain performance across various industry sectors has gained increasing attention recently (see, for instance, the works of Neely et al., 1995, 2005; Beamon, 1998, 1999; Christopher, 1998; Li and O'Brien, 1999; Gunasekaran et al., 2001, 2004; Lambert and Pohlen, 2001; Lohman et al., 2004; Govindan et al., 2017; Maestrini et al., 2018; Simão et al., 2022). While there have been many studies on measuring supply chain performance in manufacturing industry, research in the agricultural sector has been lacking. Studies have begun to develop from 2000s (see, for instance, Van der Vorst, 2000, 2005; Aramyan et al., 2006, 2007, 2009; Gellynck et al., 2008; Widyaningrum and Masruroh, 2012; Fattahi et al., 2013; Piotrowicz and Cuthbertson, 2015; Beske-Janssen et al., 2015; Govindan et al., 2017; Chopra et al., 2017; Moazzam et al., 2018; Trivellas et al., 2020). The reason for the growing attention on this topic in the agricultural sector is increasing competition as a result of globalization, which is paired with quality standard requirements, ever higher customer expectations for fresh, healthy, and safe food produced in an environmentally and socially responsible way and available 24 h per day.

Measuring the performance of the entire supply chain is important because it provides the key data for benchmarking and improving performance (Aramyan et al., 2007). Performance measurement of the supply chain brings

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together business information and market intelligence data about market conditions external to the individual firm. The general idea behind performance measurement of the supply chain is to optimize activities to reach the highest overall performance of the chain by adding value for the least possible cost. In the following, we summarize the arguments for measuring (chain) performance.

Performance measurement:

- Allows decision-makers to align their strategic activities to a strategic plan.
- Provides an overview of how well the targets are achieved.
- Provides an overview of strategic improvements and adjustments needed.
- Allows decision-makers to identify best practices and expand their usage elsewhere in the supply chain.
- Allows benchmarking against competitors.

Performance measurement systems (PMS) for agri-food supply chains face particular challenges due to specific supply chain characteristics such as seasonality, perishability and short shelf life for fresh produce, variability in output quality and quantity, the involvement of many different actors, long production times, and specialized transportation requirements (Van der Vorst, 2000; Aramyan et al., 2007).

In addition, agri-food supply chains currently face challenges from climate change, partly because the global food system is an important contributor to climate change. The Intergovernmental Panel on Climate Change estimates that '23% of total anthropogenic greenhouse gas emissions (2007–2016) derive from Agriculture, Forestry and Other Land Use (AFOLU)' (2020, p.8). In turn, climate change also threatens the future of the agri-food sector due to extreme weather events such as droughts, floods, and other effects such as changing patterns in the incidence of pests and diseases (De Vries, 2019; De Haan et al., 2019). These challenges have resulted in the rise of the concept of circular agriculture. This originates from industrial ecology (Jurgilevich et al., 2016) and aims to reduce resource consumption and emissions to the environment by closing loops in the use and loss of materials and other system inputs. This implies that, wherever possible, inputs are recovered for reuse, remanufacturing, and recycling (de Boer and van Ittersum, 2018).

More generally, in 2015, all United Nations Member States adopted the 2030 Agenda for Sustainable Development, which provides a shared blueprint for peace and prosperity for people and the planet, now and in the future. 'At its heart are the 17 Sustainable Development Goals, which are an urgent call for action by all countries – developed and developing – in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to

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preserve our oceans and forests' (https://sdgs.un.org/goals). This implies that, in the agri-food sector, farmers, agribusinesses, governments, and society must cooperate to promote inclusive, fair, and efficient food systems, including better integration of smallholder farmers into supply chains and agribusiness and improving their access to markets which are characterized by ever-changing consumption patterns (Naseer et al., 2019).

In addition, over the last few years, several countries have implemented mandatory Environmental, Social, and Governance (ESG) reporting for large companies. ESG reporting involves disclosure of performance of business operations related to ESG aspects, i.e. performance related to a business impact on the environment and society (e.g. how fairly it treats its staff and suppliers such as farmers) as well as how transparent and accountable its reporting on such issues are. Since 2022, ESG reporting, e.g. has become mandatory in UK and Canada, and in 2023, it will become mandatory in New Zealand. In the EU, currently some large companies must already disclose ESG information under the Non-Financial Reporting Directive (NFRD). However, from 2023, the NFRD will be replaced by a new ESG reporting directive – the Corporate Sustainability Reporting Directive, which will extend reporting requirements to approximately 50 000 companies across the EU.

While the performance of conventional agri-food supply chains has traditionally been measured in terms of productivity and profit, requirements for a more sustainable agriculture and circular economy require consideration of other dimensions such as measuring environmental and social performance of agri-food supply chains. Despite its importance, a recent literature review on PMS shows that studies including the concept of circular agriculture and/or circular supply chain management are limited (Vegter et al., 2021). The authors also concluded that most of the available performance measures for circular supply chain management have not yet been tested in practice and are therefore still in an early phase of development.

In this chapter, we discuss the main components of PMS, what methods of measuring supply chain performance exist, how they have evolved over time, what the challenges related to each method are, and how environmental and social indicators can be incorporated in PMS.

2 Key performance indicators for agri-food supply chains

An essential part of developing a PMS is the identification of key performance indicators (KPIs). While there are many indicators of performance that can be deployed in a supply chain, there is a small set of critical factors that disproportionally affect success or failure in the market that can be defined as KPIs.

KPIs provide quantitative information to decision-makers about their products, services, and production processes and inform decision-makers whether they are meeting their goals, whether customers are satisfied, and where improvements are necessary. KPIs are thus used to help measure progress toward achieving the strategic goals set for the supply chain.

The choice of appropriate supply chain performance indicators in agri-food supply chains is complicated due to the presence of multiple inputs and outputs in the system. While there is an extensive literature on supply chain KPIs and PMS, the literature on KPIs and effective PMS in agri-food sectors is still limited compared to other industries such as the automotive sector. Moreover, actual implementation of supply chain PMS in agri-food chains in practice is also still limited (Aramyan, 2007). It has, however, gained more importance in recent years, particularly KPIs related to green and sustainable supply chains. In 2015, Ahi and Searcy studied 445 journal articles and found 2555 performance indicators for green and sustainable supply chain management. Given the large number of performance indicators in practice, selection of the right KPIs is crucial. Supply chain actors need to develop strategic goals and set KPI targets and objectives accordingly to ensure the long-term success of the supply chain.

Creating a circular agriculture and developing sustainability strategies require quantifiable and measurable environmental and social goals. However, this has proved to be challenging (Gold et al., 2010; Beske-Janssen et al., 2015). While circularity is supposed to lead to more sustainability, it does not necessarily contribute to it. For example, 'reuse and recycle' strategies promote the return of products after end-of-use in order to reuse products or their components. This leads to less use of raw materials and hence less resource depletion and less costs. However, these returns may also require more transportation and an energy-intensive process for reusing the product or for the recycling of materials which, in turn, may generate additional CO_2 emissions and increased costs (Batista et al., 2018; Sehnem et al., 2019; Vegter et al., 2021). As a consequence, trade-offs are often required between traditional economic goals and other KPIs (e.g. relating to sustainability outcomes).

2.1 Trade-offs between KPIs

Supply chain actors typically seek to simultaneously optimize multiple objectives in their supply chain management practices, for example, improving product quality while lowering costs. However, such optimization often requires a compromise in some objectives in order to obtain benefits in others which, in its turn, requires decision-makers to make trade-offs. Examples of such trade-offs are customer service levels versus inventory holding costs, product quality versus production costs and, of course, trade-offs, between environmental,

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social, and economic objectives. In order to be successful, companies have to make decisions that enhance their margins, allow them to fulfill customer demands on quality and price in a fast and flexible manner and, at the same time, be sustainable. They must therefore evaluate trade-offs between efficient and sustainable solutions (Darvish et al., 2019). This makes it particularly important to focus on minimizing and balancing trade-offs among different objectives.

Well-defined PMS often help to guide supply chain actors in making trade-offs between performance components in order to improve the performance of the entire supply chain (Aramyan, 2007). For instance, the implementation of a specific management system (or plan or strategy) in the chain may increase the costs of the product but, at the same time, it may increase flexibility or improve food quality. If supply chain members consider food quality or flexibility as the most important aspect of performance, a trade-off can be made between increased costs versus increased flexibility or improved food quality.

Trade-offs are usually made based on an overall supply chain strategy because they influence overall chain performance and profits. In order to develop a supply chain PMS and define relevant performance indicators, supply chain operators need first to develop strategic goals and establish key objectives with KPIs to measure how well targets are being achieved. Different objectives are usually developed at strategic, tactical, and operational levels in order to allow a supply chain to measure progress toward the overall goal. The strategic level is the top level of supply chain management responsible for long-term decisions by the company (e.g. 5 years or more). The tactical level is the second level of supply chain management and involves medium-term decisions for the supply chain (e.g. over a year). The operational level involves day-to-day decision-making and planning to keep the supply chain running.

Four key supply chain pillars can be distinguished: Plan, Source, Make, and Deliver (Supply Chain Operations Reference (SCOR®), 2004). Each of these pillars has a clearly defined function in the end-to-end supply chain (see Fig. 1). Each pillar thus also affects supply chain KPIs. This has traditionally been a challenge because it requires a trade-off between economic indicators (such as inventory costs, production costs, and distribution costs) while meeting customer/market requirements for service levels. Modern day supply chain management is increasing this trade-off challenge, because responsive and efficient supply chains are no longer sufficient. In a world of disruption, resilience has emerged rapidly as a supply chain KPI together with ESG requirements (see Fig. 1). A balance should be found between efficient production with lower costs, responsive service, chain flexibility and agility, meeting sustainability requirements (e.g. ESG), and being resilient to disruption (i.e. the ability to

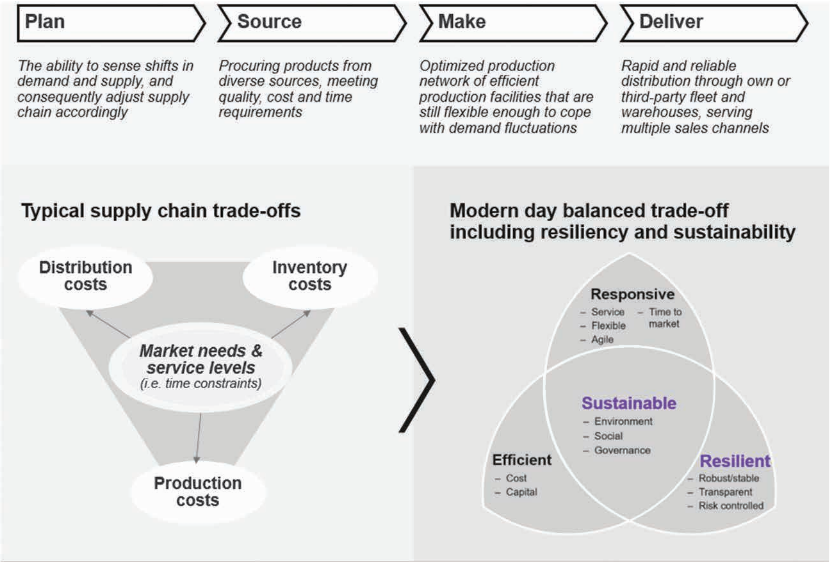

Figure 1 Supply chain trade-offs: typical vs modern. Source: Adapted from Kearney (www.kearney.com/operations-performance-transformation).

quickly and efficiently adjust operations to manage disruptions and even avoid them by minimizing the impact of events before they occur). The winning supply chains of tomorrow will be the ones that are able to break free from today's trade-off thinking and instead create win-win situations where e.g. efficiency increases while at the same time being sustainable.

3 Performance indicators and frameworks used in agri-food supply chains

As mentioned, measuring performance of agri-food supply chains is complex given their specific characteristics (Van der Vorst, 2000; Van der Spiegel, 2004; Aramyan et al., 2007). This implies that PMS developed for general supply chains will need to be adapted for agri-food supply chains, as measurement indicators such as food quality, safety, and seasonal factors will have to be considered. Important distinctions are made between daily fresh products (vegetables and fruits), chilled products (salads, dairy products, etc.), frozen products (fish, ice cream, etc.), and non-perishables such as sugar and coffee (Van der Vorst, 2000). Qualitative performance indicators that reflect consumer acceptance of the product (qualitative aspects such as taste, texture, and color) need to be considered along with other non-qualitative performance indicators (Apaiah, 2006; Aramyan et al., 2009).

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In 2000, in one of the few studies on the topic, Van der Vorst highlighted several performance indicators for food supply chains on three levels:

- Supply chain;
- Organization; and
- Process.

At supply chain level, there are five indicators, which are as follows:

- Product availability;
- Quality;
- Responsiveness;
- Delivery reliability; and
- Total supply chain costs.

At organization level, there are another five indicators, which are as follows:

- Inventory level;
- Throughput time;
- Responsiveness;
- Delivery reliability; and
- Total organizational costs.

Finally, at process level, there are four indicators, which are as follows:

- Responsiveness;
- Throughput time;
- Process yield; and
- Process costs.

In 2007, Aramyan et al. suggested a performance measurement framework with a set of performance indicators for agri-food supply chains, consisting of four components with a comprehensive set of KPIs per component (see Table 2 in Annex). The four components are as follows:

1. Efficiency, i.e. indicators dealing with how well resources are utilized, including such KPIs as company turnover, profit, and quantity of products sold.
2. Flexibility, i.e. indicators dealing with how well supply chains cope with a changing environment and with extraordinary customer service requests.

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3. Responsiveness, i.e. indicators dealing with the lead time between products requests and their delivery.
4. Food quality, i.e. dealing with product safety and health/nutritional properties, sensory properties and shelf life, and product quality aspects.

Gellynck et al. (2008) added additional performance indicators to those of Aramyan et al. (2007), such as growth in terms of market share, stability, and chain balance in agri-food chains. Later on, Fattahi et al. (2013) argued that financial, quality and safety, flexibility, customer service, efficiency, and chain coordination are useful indicators to define performance measurement of agri-food value chains. Chopra et al. (2017) applied the framework developed by Aramyan et al. (2007) to a rice supply chain and found that the rice supply chain stakeholders did not measure the importance of performance indicators equally but that all four performance indicators were relevant to rice millers and other actors in the supply chain.

4 Environmental and social performance indicators

The challenge of feeding 9 billion people by 2050 puts significant pressure on land and water resource use. Due to intensification of agri-food production, natural resources are being overexploited and negative impacts on human health are increasing (e.g. in terms of the impact of ultra-processed foods in promoting obesity). This means the environmental and socioeconomic costs associated with the externalities of the intensification of agri-food production are also increasing dramatically (Jackson et al., 2009). These costs are typically not considered in prices of food products and thus are not reflected in the performance of agri-food supply chains. There has been a more recent focus on developing performance indicators used in agri-food supply chains to reflect the cost of these externalities[1]. Gaitan Cremaschi et al. (2017) e.g. have developed a framework for measuring agri-food supply chain sustainability performance with two unique metrics, based on a total factor productivity indexing approach, to compare products in terms of their sustainability performance. Both metrics are adjusted to internalize food production's social and environmental externalities and consider the sustainability effects of different stages along agri-food supply chains. Similarly, Walkiewicz et al. (2021) have incorporated externalities related to sustainable performance activities (e.g. the time and costs of activities that create externalities or value-added) into a PMS for the German food industry. The resulting KPIs and identification

[1] Internalization of externalities refers to all measures (public or private) that guarantee that unpaid benefits or costs are considered in the composition of goods and services prices (Ding et al., 2014).

of performance and cost indicators reflected four interrelated dimensions: ecological, social, financial, and knowledge.

Dutch companies in agri-food supply chains have recently started developing schemes related to the performance of their farmers. In these schemes, farmers are rewarded for good performance and penalized for bad ('bonus-malus'). The focus of these arrangements is on sustainable agriculture in a broader sense: improving soil quality, reduced use of pesticides, enhancing water quality, lower energy use, and promoting biodiversity (Runhaar, 2016). Beyond these indicators, the implementation of a Dutch circular agricultural policy requires KPIs focused on integrated management which accounts for climate, biodiversity, and nature (Louis Bolkinstituut, 2020). An integral set of KPIs (later renamed Critical Performance Indicators (CPIs)) has been proposed to measure farmer performance/contribution to societal goals such as restoration of biodiversity, soil quality, landscape, climate and the wider environment. By adopting best management practices farmers (land users) can improve their score against CPIs. The development and implementation of CPIs are still underway. Baayen et al. (2022) suggest that it is crucial to define what issues CPIs can resolve and how a CPI system can fit into relevant governance and legislative frameworks. One of the conclusions of this study is that the prime contribution of a CPI system to enhancing sustainability in agriculture is the definition of objectives and desirable behavioral outcomes. This requires a common language, measuring methodology, and targets that all stakeholders can understand and accept.

In addition to capturing the effects of internalization of externalities on performance, there has also been a focus in recent years on issues concerning just and fair distribution of costs and profits between agri-food supply chain partners. For example, when adopting a new biomass sustainability certification system in agri-food supply chains, it was found that actors at the beginning of the supply chain (farmers/plantations) bear most of the annual certification costs, while actors at the end of the supply chain often receive most of the external benefits. There is thus a discrepancy in balancing costs and benefits in the chain. Certification systems do not have defined rules to ensure that a share of the external benefits return to the farmer (van Dam et al., 2012). Farmers in the EU often complain about the 'unfairness' of the benefits that retailers/processors receive from farmers' efforts to improve environmental or social sustainability performance. These imbalances require agri-food supply chain actors to find the ways to deal with these perceptions of unfairness. Addressing this issue is important as alignment of the perceptions of fairness among supply chain actors can improve chain performance (Bouazzaoui et al., 2020). See the example on how chocolate producer Tony Chocolonely addresses the issues of Fair Price in Box 1.

Box 1 The Living Income Reference Price of Tony Chocolonely

In 2019, Dutch chocolate brand Tony's Chocolonely whose mission is to 'make all chocolate 100% slave free' has introduced the Living Income Reference Price (LIRP). That's the price a farmer should receive for one kilo of cocoa beans to enable him or her to earn a living income. The price is based on complicated calculations, taking into account productivity, country, and family size and diversification of income. 'We think the cocoa industry has a responsibility to pay this reference price for a livable income. You too ...?' The brand is known for its 'unequally divided' chocolate bars, designed to underline the inequality in the cocoa and chocolate industries. It claims cocoa farmers in West Africa have been hard hit by increasing inflation which has forced them 'further into poverty'.

Source: https://tonyschocolonely.com/uk/en

5 Methods and techniques to measure performance

Performance measurement has evolved over time. Initially, it was a measurand solely at a firm level. Globalization and changing customer requirements have forced industries to adapt new and efficient manufacturing practices and change traditional ways of business to remain competitive. Examples of methods applied to firm-level performance measurement are Activity-Based Costing (ABC) and Balanced Scorecard and Economic Value-added (EVA).

As agri-food supply chains have become more complex, and with increasing performance requirements in terms of cost, speed, flexibility, resilience, and sustainability, there is a growing need to measure overall supply chain performance. Some existing methodologies, like Balanced Scorecard, have been extended to measure supply chain performance. New methodologies have also been developed. One of the first methods to measure supply chain performance was the SCOR model developed by the Supply Chain Council in 2004. While previous methods focused largely on economic performance and aimed to enhance supply chain returns and profitability, more recent performance measurement methodology has also focused on sustainability aspects and accounting for environmental and social impacts. Examples of such methods are Life-Cycle Assessment (LCA) and True Price and/or Fair Price assessments. Table 1 provides a short overview of different performance measurement methods, including a summary of the advantages and disadvantages of these methods.

Table 1 Performance measurement methods

Method	Advantages	Disadvantages
Activity-Based Costing (ABC)	• Gives more than just financial information • Recognizes the changing cost behavior of different activities	• Costly data collection • Difficulties to collect initial required data • Heavily relies on financial indicators • Difficulties to determine appropriate and acceptable costs drivers
Balanced Scorecard	• Balanced view about the performance • Financial and non-financial factors • Top-level strategy and middle management-level actions are clearly connected and appropriately focused	• Not a quick fix • Complete implementation should be staged
Economic Value-Added (EVA)	• Considers the cost of capital • Allows projects to be viewed separately	• Computation's difficulties • Difficult to allocate EVA among divisions
Life-Cycle Assessment (LCA)	• Allows to establish comprehensive baselines of information on a product's or processor's resource requirement • Allows to identify areas where the greatest reduction of environmental burdens can be achieved • Possibility to assess the cost and environmental effects associated with life cycle of a product or process	• Data-intensive methodology • Product-level analysis • Lack of confidence in the LCA methodology
Supply Chain Council's SCOR Model	• Takes into account the performance of overall supply chain • Balanced approach • Performance of supply chain in multiple dimensions	• Does not attempt to describe every business process or activity • Does not explicitly address training, quality, information technology, and administration
True price	• Takes into account the performance of overall supply chain • Considers costs of externalities which can be reflected in the performance of agri-food supply chains	• Data-intensive methodology • Calculating it requires defining what can be considered sustainable (and unsustainable) in the economy • Difficult to monetize externalities • Still under development
Fair price	• Takes into account a fair distribution of costs and benefits for all chain actors • Analyses the aspects that affect the distribution of costs and the prices in agricultural value chains in relation to fairness	• Data-intensive methodology • Difficult to monetize fairness perceptions • Still under development

Methods for measuring supply chain performance include the following:

- *ABC:* The ABC method is based on accounting methods and involves breaking down activities into individual tasks or cost drivers, while estimating the resources (i.e. time and costs) needed for each one. Costs are then allocated to these cost drivers, including allocating overhead costs either equally or based on ranking cost drivers. This approach allows for better assessing the productivity and costs of a supply chain process. Using the ABC method means that companies can more accurately assess, for instance, the costs of services for a specific customer or the costs of marketing a specific product. Businesses can then understand the factors that drive each major activity, the costs of activities, and the relationship between activities and products. ABC analysis does not replace traditional financial accounting but provides a better understanding of performance by looking at the same numbers in a different way (Lapide, 2000).
- The *Balanced Scorecard* is a popular performance measurement scheme initially developed by Kaplan and Norton (1992). This method employs performance metrics from different perspectives:
    - Financial (e.g. cost of manufacturing and cost of warehousing);
    - Customer (e.g. on-time delivery and order fill rate);
    - Business process (e.g. manufacturing adherence-to-plan); and
    - Innovation and technology perspective (e.g. new product development cycle time).

By combining these different perspectives, the Balanced Scorecard helps a manager to understand the interrelationships and trade-offs between alternative performance metrics and leads to improved decision-making. This method is not specifically designed for supply chains but could be adapted to focus on supply chain performance. The Balanced Scorecard is more tactical and strategically oriented compared with the SCOR® model which is an operation-oriented method.

- The *Supply Chain Council's* SCOR® Model is a standard supply chain process reference model designed to fit all industries (Supply-Chain Council, 2004). This model provides guidance on the types of metrics decision-makers can use to develop a balanced approach toward measuring the performance of an overall supply chain. The SCOR® Model advocates a set of supply chain performance indicators as a combination of the following:

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1. Reliability measures (e.g. fill rate, perfect order fulfillment);
2. Cost measures (e.g. cost of goods sold);
3. Responsiveness measures (e.g. order fulfillment lead time); and
4. Asset measures (e.g. inventories).

The SCOR® Model directly addresses the needs of supply chain management at the operational level. One of the tenets of the SCOR® Model is that a supply chain must be measured and described in multiple dimensions. These dimensions include reliability, responsiveness, flexibility, cost, and efficiency of asset utilization. The SCOR model is a cross-industry model that breaks down the processes within a supply chain into five primary processes: plan, sources, make, deliver, and return. Supply chain success depends on the success of each process. The model provides a best practice view of supply chain processes.

- *EVA*: This method is based on the assumption that shareholder value is increased when a company earns more than its cost of capital. Unlike balanced scorecards, which offer a functional focus toward performance, the EVA offers a project focus. EVA attempts to quantify value created by an enterprise, based on the operating profits in excess of capital employed (through debt and equity financing). EVA metrics are less useful for measuring detailed supply chain performance. They can be used, however, as supply chain metrics within an executive-level performance scorecard and can be included in other measurement systems such as The Logistics Scoreboard approach (Lapide, 2000).
- *LCA* involves making detailed measurements of input use and environmental waste during the production of a product, from the mining of the raw materials used in its production and distribution through to its use, possible reuse or recycling, and its eventual disposal. LCA has thus far focused on the environmental burden a product poses throughout its life. It offers possibilities for extension to include economic performance, when combined with life-cycle cost assessment methods (Azapagic and Clift, 1999; Hagelaar and Van der Vorst et al., 2009; Carlsson-Kanyama et al., 2003). Using the life-cycle cost assessment method, it is possible to integrate economic and environmental cost information into the LCA framework and assess the cost and environmental effects associated with the life cycle of a product or process.
- *True price* is a more recent method which has grown in popularity. It is a methodology that accounts for the external costs of societal impacts (be it environmental or social) in the value chain of an agricultural

product. True pricing entails the quantification of externalities and their expression in monetary terms in a way that is comparable to a product's market price (Galgani et al., 2021). The true price is a way of accounting for negative consequences of production and consumption at the product level, expressed as costs in monetary terms. The sum of environmental and social costs is called the true price gap. The true price of a product is defined as the sum of the market price and the true price gap, and this is the price a buyer would have to pay for a product if the cost of remediating its unsustainable externalities were added on top of its price. The lower the true price gap, the less social and environmental costs a product has (Galgani et al., 2021). See the example of the shop in Amsterdam that sells products with a 'true price' in Box 2.

- *Fair price* is very often used in combination with True Price and refers to True and Fair Price methodology. Despite this, there is a substantial difference between these two methods. While True price considers the costs of externalities in the price of the product, in Fair Price, a key issue is whether the (additional) costs of sustainability and risks that are linked to producing a product in a more sustainable manner are fairly distributed between the actors in the value chain. Furthermore, if a market needs to be established for more sustainable products, the question arises whether (enough) consumers are willing to pay. What prices, or any other market outcomes, are (un)fair in agricultural value chains follows from an economic notion of (in)efficient markets and economic behavior, as well as from personal and societal ethics and perceptions of market actors involved. The discussion about fair or just prices appeals to moral notions such as a fair distribution of remuneration for all parties and their performance in the food chain. This methodology is currently under development. Analysis of factors that affect the distribution of costs and the prices in agricultural value chains in relation to fairness, including practical guidance for value chain actors, is being developed in research programs such as follows: True and Fair Price for Sustainable Products (see more at https://www.wur.nl/en/project/True-and-fair-price-for-sustainable-products.htm). The framework links economic models (e.g. neo-classical, industrial, transaction costs) to a construct of subjectively perceived fairness (see e.g. Diller, 2008). The framework is built on the links between fairness in value chains and chain performance and includes goals (justice), norms and rules, fairness perceptions, behavior, relationship quality, and performance.

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Box 2 New Amsterdam store sells goods at the price required to avoid pollution, exploitation and climate change

Paying the true price for a better world

Now open every Saturday in the heart of the famed Amsterdam shopping district Haarlemmerdijk, True Price Store is offering products 'free from poverty, exploitation, pollution, destruction and climate change', according to Michel Scholte, director of external affairs for the social enterprise True Price.

The store will begin by selling coffee, chocolate, and bread, before expanding its repertoire and opening hours. Meanwhile, the store hopes to already stand as an example to other retailers, restaurants, and supermarkets, encouraging them to follow suit ...

The true – and fair – cost …

So, what is the true price of goods? 'It differs per product', explains Scholte. 'We show what a product actually costs society in addition to the market price. For example, jeans here cost €40 plus €33 more, a t-shirt cost €15 plus €8, a chocolate bar €2.79 plus 90 cents, a café latte €3.50 plus 25 cents, and a loaf of bread €3.25 plus 18 cents'.

'At this moment we, only voluntarily charge a small part of that: the costs for climate change and underearning of farmers. And this money is then redirected to reforestation and supporting the extreme poor. However, this is just a part of the total true price gap', says Scholte. 'We still need to not only improve these remediations, but also address 29 other social and environmental impacts, including water, soil, air and the treatment of workers', says Scholte. 'Only then will we have a truly sustainable product'.

Source: Iamsterdam, 2020. https://www.iamsterdam.com/en/business/news-and-insights/news/2020/true-price-store

6 Conclusion and future trends

Methods for performance measurement of businesses have existed for centuries. However, the concept of measuring performance of entire supply chains is relatively young. Traditionally, most organizations have viewed themselves as entities that exist independently from others and need to compete with each other in order to survive. Increasingly, organizations are now focusing on their core business (i.e. the activities that they do really well and where they have competitive advantage over other organizations), while any other activities and products are procured from other organizations. This trend toward outsourcing and globalization has been a major development in global business. To effectively manage and control a chain of organizations, involvement of all supply chain members is necessary. Organizations are thus forced to look beyond the performance of their own organization, focusing also on the performance of the entire supply chain. Performance measurement of agri-food supply chains has, until the last decade, received little research attention. Recently, due to increasing globalization and competition in the world market, rising consumers' demands, governmental regulations of food quality, and the greater prominence of sustainability issues, measuring performance of agri-food supply chains has become a topic of interest for many researchers. Starting from the beginning of the twenty-first century, the number of papers devoted to this issue has increased and is expected to increase even further.

Organizations in the agri-food sector are generally interested in the implications and benefits that a supply chain approach to performance measurement could bring. However, the actual practice of implementing a supply chain PMS in agri-food supply chains is still limited. One of the reasons is the many difficulties in measuring the performance of organizations that have no legal power or other form of authority over each other. Moreover, most of the available performance measures related to circular supply chain management have not yet been tested in practice and are therefore still in an early phase of development.

Future research on supply chain PMS has to pay explicit attention to these challenging issues of enabling chain members to come to mutual agreement to implement such PMS. No system, however, skillfully designed, will make a difference unless supply chain members come to an agreement to support and use it in their daily practice. It is difficult to develop and adopt PMS that satisfy the needs of all stakeholders and ensures maximum value to end-users (consumers) (Mishra et al., 2018). For a PMS to be functional, it needs to fit the environment in which it operates (Ramos et al., 2022). Measurement criteria can be specific for each type of supply chain (Najmi and Makui, 2012). Different industries will require different metrics based on their supply chain performance characteristics and specific business environments (Bulsara et al., 2016; Govindan et al., 2017). A key issue in performance measurement is to determine which goal it is designed to support. Increasing social and environmental concerns are forcing supply chain actors to balance the economic, environmental, and social dimensions of their business. To be efficient, companies must now evaluate the trade-offs between efficient versus sustainable solutions. It is important therefore to focus on finding win-win solutions able to generate efficient and sustainable solutions that bring benefits to all supply chain actors.

Measuring performance of agri-food supply chains is complex due to specific characteristics such as seasonality, food quality, and safety issues. Sustainability challenges require inclusion of environmental and social performance indicators in PMS alongside more traditional economic performance indicators. While previous supply chain PMS aimed mainly at enhancing supply chain returns and profitability, focusing mainly on financial and economic performance indicators, current performance measurement urgently requires inclusion of more sustainability indicators and accounting for environmental and social impacts. As a result, new performance measurement methodologies such as True and Fair Price are currently being pioneered. It is expected that this trend will continue in years to come, given such urgent challenges as climate change and increasing concern about societal impacts of business activities.

As discussed, it is expected that future research will focus on further development of performance measurement methodologies such as True and Fair Price, since calculation of the costs of externalities will most likely become mandatory for all supply chain actors in future (including agri-food supply chains), requiring a reliable methodology to achieve this goal. This trend is already notable with growing mandatory ESG reporting, which requires reliable KPIs to objectively demonstrate a company's progress in ESG aspects of its operations against generally agreed benchmarks and targets. As the global food system is an important contributor to climate change, agri-food supply chain actors will be increasingly forced to comply with legislation related to reducing negative environmental impacts, thus introducing new business models with a robust set of KPIs where costs are balanced against performance, resilience, sustainability, and social equity.

7 Where to look for further information

To delve deeper into the complex world of agri-food supply chain performance measurement, various sources can be explored. The academic literature in the fields of supply chain management, agriculture, and sustainability can provide in-depth insights into the subject. For this, explore academic journals such as the *Journal of Supply Chain Management*, *Agricultural Systems*, *Food Policy*, and *Journal of Agricultural and Food Industrial Organization*. These journals often publish research articles, case studies, and reviews related to agri-food supply chain performance measurement. The following authors are the frontrunners on the topic of supply chain performance: Neely et al., 1995, 2005; Beamon, 1998, 1999; Christopher, 1998; Gunasekaran et al., 2001, 2004; Lambert and Pohlen, 2001; Lohman et al., 2004; Govindan et al., 2017;

Maestrini et al., 2018; and Simão et al., 2022. For performance measurement specifically in the agricultural sector, see Van der Vorst, 2000, 2005; Aramyan et al., 2006, 2007, 2009; Gellynck et al., 2008; Widyaningrum and Masruroh, 2012; Fattahi et al., 2013; Piotrowicz and Cuthbertson, 2015; Beske-Janssen et al., 2015; Govindan et al., 2017; Chopra et al., 2017; Moazzam et al., 2018; and Trivellas et al., 2020.

Additionally, industry reports, white papers and reports from organizations such as the Food and Agriculture Organization of the United Nations (FAO) (see for instance some developed performance tools at https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1257355/), and global consulting firms can provide practical applications and case studies. Explore for instance performance measurement topics related to a supply chain resilience and strategic insights at the website of Kearney https://www.kearney.com/service/operations-performance/kearney-supply-chain-institute and https://www.kearney.com/service/operations-performance/kearney-supply-chain-institute. Visit websites of SCOR models such as https://scor.ascm.org or https://scmedu.org/scor/.

For studies related to true and fair prices visit websites:

- https://www.wur.nl/en/project/true-and-fair-price-for-sustainable-products.htm.Logatcheva, et al., 2023. True Cost Accounting (TCA): a methodology for making the global food system more sustainable (wur.nl).
- Taufik, D., Reinders, M. J. and van Haaster-de Winter, M. A. (2023). Creating trust and consumer value for true price food products, *Journal of Cleaner Production*, 390, 136145, ISSN 0959-6526. doi:10.1016/j.jclepro.2023.136145.
- Galgani, P., Woltjer, G., de Adelhart Toorop, R. and Ruiz, A. G. (2021). Fossil fuel and other non-renewable material depletion: true pricing method for agri-food products. https://edepot.wur.nl/558072.
- https://trueprice.org/.

8 References

Apaiah, R. K. (2006). Designing food supply chains-a structured methodology: A case on novel protein foods, PhD-Thesis, Wageningen University, Wageningen.

Aramyan, L. (2007). Measuring supply chain performance in the agri-food sector. PhD Thesis, Wageningen university, Available at: https://edepot.wur.nl/121904.

Aramyan, L., Ondersteijn, C., Kooten, O. and Oude Lansink, A. (2006). Performance indicators in agri-food production chains. In: Ondersteijn (Ed.). *Quantifying the Agri-Food Supply Chain*, Springer, Dordrecht 49–66.

Aramyan, L. H., Oude Lansink, A. G. J. M., van der Vorst, J. G. A. J. and van Kooten, O. (2007). Performance measurement in agri-food supply chains: a case study, *Supply Chain Management* 12(4), 304–315.

Azapagic, A. and Clift, R. (1999). The application of life cycle assessment to process optimisation, *Computers and Chemical Engineering* 23(10), 1509–1526.

Batista, L., Bourlakis, M., Smart, P. and Maull, R. (2018). In search of a circular supply chain archetype–a content-analysis-based literature review, *Production Planning and Control* 29(6), 438–451.

Beamon, B. M. (1998). Supply chain design and analysis: models and methods, *International Journal of Production Economics* 55(3), 281–294.

Beamon, B. M. (1999). Measuring supply chain performance, *International Journal of Operations and Production Management* 19(3), 275–292.

Beamon, B. M. (1999b). Designing the green supply chain, *Logistics Information Management* 12(4), 332–342.

Berry, L. (2006). *On Great Service: A Framework for Action*, Free Press, New York.

Beske-Janssen, P., Johnson, M. P. and Schaltegger, S. (2015). 20 years of performance measurement in sustainable supply chain management – what has been achieved?, *Supply Chain Management* 20(6), 664–680. https://doi.org/10.1108/SCM-06-2015-0216.

Bouazzaoui, M., Wu, H. J., Roehrich, J. K., Squire, B. and Roath, A. S. (2020). Justice in inter-organizational relationships: A literature review and future research agenda, *Industrial Marketing Management* 87, 128–137.

Bowersox, D. J. and Closs, D. J. (1996). *Logistical Management: the Integrated Supply Chain Process*, McGraw-Hill, New York.

Bulsara, H. P., Qureshi, M. N. and Patel, H. (2016). Green supply chain performance measurement: an exploratory study, *International Journal of Logistics Systems and Management* 23(4), 476–498.

Carlsson-Kanyama, A., Pipping Ekström, M. and Shanahan, H. (2003). Food and life cycle energy inputs: consequences of diet and ways to increase efficiency, *Ecological Economics* 4, 293–307.

Chopra, S., Laux, C., Schmidt, E. and Rajan, P. (2017). Perception of performance indicators in an agri-food supply chain: A case study of India's public distribution system, *International Journal on Food System Dynamics* 8, 130–145.

Christopher, M. G. (1998). *Logistics and Supply Chain Management; Strategies for Reducing Costs and Improving Services*, Pitman Publishing, London.

Darvish, M., Archetti, C. and Coelho, L. C. (2019). Trade-offs between environmental and economic performance and inventory-routing problems, *International Journal of Production Economics* 217(C), 269–280.

de Boer, I. J. M. and van Ittersum, M. K. (2018). *Circularity in Agricultural production*. Wageningen University & Research. Available at: https://edepot.wur.nl/470625.

de Vries, B. J. M. (2019). Engaging with the sustainable development goals by going beyond modernity: an ethical evaluation within a worldview framework, *Global Sustainability* 2, e18. https://doi.org/10.1017/sus.2019.15.

de Haan, F. J., Ferri, D. Q., Walsh, S. J. and Bettencourt, L. M. A. (2019). Scales 1668 and transformative change: transitions in the Galapagos. In: Kvan, T. and Karakiewicz, J. (Eds.). *Urban Galapagos: Transition to Sustainability in Complex Adaptive Systems*, Springer, Cham, 43–58. https://doi.org/10.1007/978-3-319-99534-2_4.

Diller, H. (2008). Price fairness, *Journal of Product and Brand Management* 17(5), 353–355.

Ding, H., He, M. and Deng, C. (2014). Lifecycle approach to assessing environmental friendly product project with internalizing environmental externality, *Journal of Cleaner Production* 66, 128–138.

Fattahi, F., Nookabadi, A. S. and Kadivar, M. (2013). A model for measuring the performance of the meat supply chain, *British Food Journal* 115(8), 1090–1111.

Gaitan Cremaschi, D., Meuwissen, M. P. M. and Oude Lansink, A. G. J. M. (2017). Total factor productivity: a framework for measuring agri-food supply chain performance towards sustainability, *Applied Economic Perspectives and Policy* 39(2), 259–285.

Galgani, P., Woltjer, G., de Adelhart Toorop, R. and Groot Ruiz, A. (2021). Valuation framework for true Price assessment of agri-food products, *Report of the Project w PPS AF18051/ TU18104 'True and Fair Price for Sustainable Products'*, Available at: https://trueprice.org/valuation-framework-for-true-price-assessment-of-agrifood-products/.

Gellynck, X., Molnar, A. and Aramyan, L. H. (2008). Supply chain performance measurement: the case of the traditional food sector in the EU, *Journal on Chain and Network Science* 8(1), 47–58. https://doi.org/10.3920/JCNS2008.x088.

Gold, S., Seuring, S. and Beske, P. (2010). 'Sustainable supply chain management and interorganizational resources: A literature review', Corp. Soc. Responsib, *Environmental Management* 17, 230–245.

Govindan, K., Mangla, S. K. and Luthra, S. (2017). Prioritising indicators in improving supply chain performance using fuzzy AHP: insights from the case example of four Indian manufacturing companies, *Production Planning and Control* 28(6–8), 552–573.

Gunasekaran, A., Patel, C. and Tirtiroglu, E. (2001). Performance measures and metrics in a supply chain environment, *International Journal of Operations and Production Management* 21(1/2), 71–87.

Gunasekaran, A., Patel, C. and McGaughey, R. E. (2004). A framework for supply chain performance measurement, *International Journal of Production Economics* 87(3), 333–347.

Hagelaar, G. J. L. F. and Van der Vorst, J. G. A. J. (2002). Environmental supply chain management: using life cycle assessment to structure supply chains, *International Food and Agribusiness Management Review* 4, 399–412.

Hobs, J. E. and Young, L. M. (2000). Closer vertical co-ordination in agri-food supply chains: a conceptual framework and some preliminary evidence, *Supply Chain Management: an International Journal* 5(3), 131–143.

Jackson, P., Ward, N. and Russell, P. (2009). Moral economies of food and geographies of responsibility, *Transactions of the Institute of British Geographers* 34(1), 12–24.

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L. and Schösler, H. (2016). Transition towards circular economy in the food system, *Sustainability* 8(1), 69. https://doi.org/10.3390/su8010069.

Kaplan, R. S. and Norton, D. P. (1992). The balances scorecard- measures that drive performance, *Harvard Business Review* 70(1), January–February, 71–79.

Lai, K. H., Ngai, E. W. T. and Cheng, T. C. E. (2002). Measures for evaluating supply chain performance in transport logistics, *Transportation Research Part E: Logistics and Transportation Review* 38(6), 439–456.

Lambert, D. M. and Pohlen, T. L. (2001). Supply chain metrics, *The International Journal of Logistics Management* 12(1), 1–19.

Lohman, C., Fortuin, L. and Wouters, M. (2004). Designing a performance measurement system: a case study, *European Journal of Operational Research* 156(2), 267–286.

Lapide, L. (2000), *'What about measuring supply chain performance?', White Paper, (Ascet, 2, April 15)*, Available at: http://lapide.ASCET.com.

Li, D. and O'Brien, C. (1999). Integrated decision modelling of supply chain efficiency, *International Journal of Production Economics* 59(1–3), 147–157.

Luning, P. A., Marcelis, W. J. and Jongen, W. M. F. (2002). *Food Quality Management: A Techno Managerial Approach*, Wageningen Academic Publishers, Wageningen.

Maestrini, V., Luzzini, D., Caniato, F., Maccarrone, P. and Ronchi, S. (2018). Measuring supply chain performance: a lifecycle framework and a case study, *International Journal of Operations and Production Management* 38(4), 934–956.

Mishra, D., Gunasekaran, A., Rameshwar, D. and Papadopoulos, T. (2018). Supply chain performance measures and metrics: a bibliometric study: a bibliometric study', *Benchmarking: an International Journal* 25(3), 932–967.

Moazzam, M., Akhtar, P., Garnevska, E. and Marr, N. E. (2018). Measuring agri-food supply chain performance and risk through a new analytical framework: a case study of New Zealand dairy, *Production Planning and Control* 29(15), 1258–1274.

Najmi, A. and Makui, A. (2012). A conceptual model for measuring supply chain's performance, *Production Planning and Control* 23(9), 694–706.

Naseer, M. A. R., Ashfaq, M., Hassan, S., Abbas, A., Razzaq, A., Mehdi, M., Ariyawardana, A. and Anwar, M. (2019). Critical issues at the upstream level. In sustainable supply chain management of agri-food industries: evidence from Pakistan's citrus industry, *Sustainability* 11(5), 1326.

Neely, A., Gregory, M. and Platts, K. (1995). Performance measurement system design: a literature review and research Agenda, *International Journal of Operations and Production Management* 15(4), 80–116.

Neely, A., Gregory, M. and Platts, K. (2005). Performance measurement system design, *International Journal of Operations and Production Management* 25(12), 1228–1263.

Persson, F. and Olhager, J. (2002). Performance simulation of supply chain designs, *International Journal of Production Economics* 77(3), 231–245.

Piotrowicz, W. and Cuthbertson, R. (2015). Performance measurement and metrics in supply chains: an exploratory study, International Journal of Productivity and Performance Management 64(8), 1068–1091. https://doi.org/10.1108/IJPPM-04-2014-0064.

Ramos, E., Coles, P. S., Chavez, M. and Hazen, B. (2022). Measuring agri-food supply chain performance: insights from the Peruvian kiwicha industry, *Benchmarking: An International Journal* 29(5), 1484–1512.

Runhaar, H. (2016). Towards 'nature-inclusive' Agriculture, *Inaugural Lecture upon Taking up the Position of Special Professor of Management of Biodiversity and Agricultural Landscapes at Wageningen University on 22 September 2016*, Available at: https://edepot.wur.nl/389369.

Sehnem, S., Vazquez-Brust, D., Pereira, S. C. F. and Campos, L. M. S. (2019). Circular economy: benefits, impacts and overlapping, *Supply Chain Management* 24(6), 784–804.

Simão, L. E., Somensi, K., Dávalos, R. V. and Rodriguez, C. M. T. (2022). Measuring supply chain performance: the triple E model, *International Journal of Productivity and Performance Management* 71(7), 2951–2969.

Supply Chain Council (2004). Available at: http://www.supply-chain.org.

Trivellas, P., Malindretos, G. and Reklitis, P. (2020). Implications of green logistics management on sustainable business and supply chain performance: evidence from a survey in the Greek Agri-food sector, *Sustainability* 12(24), 10515.

Valeeva, N. I. (2005). *Cost-Effectiveness of Improving Food Safety in the Dairy Production Chain*, PhD thesis, Wageningen University, Wageningen.

van Dam, J., Ugarte, S. and van Iersel, S. (2012). Selecting a biomass certification system – a benchmark on level of assurance, costs and benefits, *NL Agency, Ministry of Economic Affairs, Agriculture and Innovation*, Available at: https://edepot.wur.nl/200883.

Van der Spiegel, M. (2004). *Measuring Effectiveness of Food Quality Management*, PhD thesis, Wageningen University, Wageningen SCOR, Supply Chain Council (2004). Available at: http://www.supply-chain.org.

Van der Vorst, J. G. A. J. (2000). Effective food supply chains. Generating, modelling and evaluation supply chain scenarios, PhD thesis, Wageningen University, Wageningen.

Van der Vorst, J. G. A. J. (2005). Performance measurement in agri-food supply chain networks. An overview. In: Ondersteijn, C. J., Wijnands, J. H., Huirne, R. B. and van Kooten, O. (Eds), Springer, Dordrecht. *Quantifying Supply Chains*.

Van Der Vorst, J. G. A. J., Tromp, S. and Van Der Zee, D. (2009). Simulation modelling for food supply chain redesign; integrated decision making on product quality, sustainability and logistics, *International Journal of Production Research* 47(23), 6611–6631.

Vegter, D., Hillegersberg, J. and Olthaar, M. (2021). Performance measurement systems for circular supply chain management: current state of development, *Sustainability* 13(21), 12082, Available at: https://doi.org.

Walkiewicz, J., Lay-Kumar, J. and Herzig, C. (2021). The integration of sustainability and externalities into the "corporate DNA": a practice-oriented approach, *Corporate Governance* ahead–of(ahead–of) 21(3), 479–496. https://doi.org/10.1108/CG-06-2020-0244.

Widyaningrum, D. and Masruroh, N. A. (2012). Development of the sea fishery supply chain performance measurement system: A case study, *International Journal of Supply Chain Management (IJSCM)* 1(3), 20–32.

Womack, J. and Jones, D. (2002). *Seeing the Whole: Mapping the Extended Value Stream*, Lean Enterprise Institute, Cambridge.

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Annex

Table 2 Definitions of performance indicators used in the framework of Aramyan et al. (2007)

Categories *Indicators*	Definitions	Measures
Efficiency[a]		
Production costs/ Distribution costs	Combined costs of raw materials and labor in producing goods/ Combined costs of distribution, including transportation and handling cost	The sum of the total costs of inputs used to produce output/services (fixed and variable costs)
Transaction costs	The costs other than the money price that are incurred in trading goods or services(e.g. searching cost, negotiation costs, and enforcement costs)	The sum of searching costs (the costs of locating information about opportunities for exchange), negotiation costs (costs of negotiating the terms of the exchange), and enforcement costs (costs of enforcing the contract)
Profit	The positive gain from an investment or business operation after subtracting all expenses	Total revenue less expenses
Return on investments	A measure of a firm's profitability and measures how effectively the firm uses its capital to generate profit	Ratio of net profit to total assets
Inventory	A firm's merchandise, raw materials, and finished and unfinished products which have not yet been sold.	The sum of the costs of warehousing of products, capital, and storage costs associated with stock management and insurance
Flexibility[a]		
Customer satisfaction	The degree to which the customers are satisfied with the products or services	The percentage of satisfied customers to unsatisfied customers
Volume flexibility	The ability to change the output levels of the products produced	Calculated by demand variance and maximum and minimum profitable output volume during any period of the time
Delivery flexibility	The ability to change planned delivery dates	The ratio of the difference between the latest time period during which the delivery can be made and the earliest time period during which the delivery can be made and the difference between the latest time period during which the delivery can be made and the current time period

(*Continued*)

Table 2 (*Continued*)

Categories *Indicators*	Definitions	Measures
Backorders	An order that is currently not in stock, but is being re-ordered (the customer is willing to wait until re-supply arrives) and will be available at a later time	The proportion of the number of backorders to a total number of orders
Lost sales	An order that is lost due to the stock out, because the customer is not willing to permit the backorder	The proportion of the number of lost sales to a total number of sales
Responsiveness[a]		
Fill rate	Percentage of units ordered that are shipped on a given order	Actual fill rate is compared to the target fill rate
Product lateness	The amount of time between the promised product delivery date and the actual product delivery date	Delivery date minus due date
Customer response time	The amount of time between an order has been done and its corresponding delivery	The difference between the amount of the time an order has been done and its corresponding delivery
Lead time	Total amount of time required to produce a particular item or service	Total amount of time required to complete one unit of product or service
Customer complaints	The registered complaints from customers about product or service	The total number of complaints registered
Shipping errors	Wrong products shipments	The percentage of wrong shipments
Product quality[b]		
Sensory properties and shelf life		
Appearance	First sight of the tomato, combination of different attributes (color, size and form, firmness, lack of blemishes and damages)	Number of damages, color scale, size, and form scale
Taste	Determined by the sweetness, mealiness, and aroma of a vegetable/fruit	Brix value, which is the measurement of a soluble dry substance in a liquid (providing an approximate measure of sugar content)

(*Continued*)

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Table 2 (*Continued*)

Categories *Indicators*	Definitions	Measures
Shelf life	The length of time a packaged food will last without deteriorating	The difference in time between harvesting or processing and packaging of the product and the point in time at which it becomes unacceptable for consumption
Product safety and health		
Salubrity	The quality of the products being healthful and nutritious	Nutritional value and lycopene content
Product safety	Product does not exceed an acceptable level of risk associated with pathogenic organisms or chemical and physical hazards such as microbiological, chemical contaminant in products, and micro-organisms	Lab checks and monitoring processes according to certification schemes
Product reliability and convenience		
Product reliability	Refers to the compliance of the actual product composition with the product description	Number of registered complaints
Convenience	The information provided on the packaging is useful, complete, and easily understandable	Number of registered complaints
Process quality[b]		
Production system characteristics		
Traceability	Traceability is the ability to trace the history, application, or location of an product using recorded identifications	Information availability, use of barcodes, and standardization of quality systems
Storage and transport conditions	Standard conditions required for transportation and storage of the products that is optimal for good quality	Measure of relative humidity and temperature, complying with standard regulations
Working conditions	Standard condition that ensure a hygienic, safe working environment, with correct handlings and good conditions	Compliance with standard regulations
Environmental aspects		
Energy use	The amount of energy used during production process	The ratio of cubic meter gas used per square meter glasshouse

(*Continued*)

Table 2 (*Continued*)

Categories *Indicators*	Definitions	Measures
Water use	The amount of water used during production process	The ratio of a liter water used per square meter land under the vegetables
Pesticide use	A permitted amount of pesticides used in production process	The amount and the frequency of the pesticide use complying with standard regulations
Recycling/reuse	Collected used product from crop, packaging etc. that is disassembled, separated, and processed into recycled products, components, and/or materials or re-used, distributed, or sold as used, without additional processing	Percentage of materials recycled/re-used
Marketing		
Promotion	Activities intended to increase market share for product (e.g. branding, pricing, and labeling)	Increase in number of customers and sales
Customer service	The provision of labor and other resources, for the purpose of increasing the value that buyers receive from their purchases and from the processes leading up to the purchase	Ratio of provision of resources used to increase customer service to increased sales
Display in stores	Demonstration of the product in the store	Increase in number of customers and sales

[a]Sources: Beamon, 1998, 1999a; Bowersox and Closs, 1996; Hobbs and young, 2000; Persson and Olhager, 2002; Lai et al., 2002; Womack and Jones, 2002; Gunasekaran et al., 2001; SCOR model, 2004; Berry, 2006.
[b]Sources: Luning et al., 2002; Van der Spiegel, 2004; Valeeva, 2005; Beamon, 1999b; Berry, 2006.