CHAPTER 5

PERFORMANCE INDICATORS IN AGRI-FOOD PRODUCTION CHAINS

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Abstract. The last decade has seen an increasing interest in indicators of supply-chain performance. A large number of various performance indicators have been used to characterize supply chains, ranging from highly qualitative indicators like customer or employee satisfaction to quantitative indicators like return on investments. This large number of different performance indicators, and the lack of consensus on what determines performance of supply chains, complicates the selection of performance measures. Furthermore, combining these indicators into one measurement system proves to be difficult. Efforts as well as progress have been made in this area but supply-chain performance measurement received little or no attention in the field of food and agribusiness. This paper provides a literature review on existing performance indicators and models, and discusses their usefulness in agri-food supply chains. Furthermore, based on this overview, a conceptual framework is developed for further research in this area.
Keywords: measure; efficiency; responsiveness; flexibility; food quality; framework

INTRODUCTION

A supply chain is generally defined as a network of physical and decision-making activities connected by material and information flows that cross organizational boundaries (Van der Vorst 2000). According to Lambert and Cooper (2000) there are four main characteristics of a supply chain: first it goes through several stages of increasing intra- and inter-organizational, vertical coordination. Second, it includes many independent firms, suggesting that managerial relationship is essential. Third, a supply chain includes a bi-directional flow of products and information and the managerial and operational activities. Fourth, chain members aim to fulfil the goals to provide high customer value with an optimal use of resources. An agri-food chain

C.J.M. Ondersteijn, J.H.M. Wijnands, R.B.M. Huirne and O. van Kooten (eds.), Quantifying the agri-food supply chain,47-64.
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is nothing more than a supply chain which produces and distributes an agricultural or horticultural product and where product flows and information flows take place simultaneously (Bijman 2002).What makes agri-food supply chains different from other supply chains is (1) the nature of production, which is partly based on biological processes, thus increasing variability and risk; (2) the nature of the product, which has specific characteristics like perishability and bulkiness that require a certain type of supply chain; and (3) the societal and consumer attitudes towards issues like food safety, animal welfare and environmental pressure.

Within a chain, coordination may take various forms: vertical integration, long-term contracts or market transactions. Recent studies have shown that in agri-food supply chains, transactions are undergoing several changes (Bijman 2002). Most agri-food sectors are moving closer to vertical coordination. Some industries (e. g. poultry) developed tight vertical coordination some time ago, while in others it is a relatively new phenomenon (Hobbs and Young 2000) The major change is the shift from a production orientation to a market orientation in the strategy of producers. This change leads to an increase in the information exchange among agri-food chain members. Another change relates to product innovation, which has become very important in agri-food chains. All these changes are the result of an increasing consumer demand for more quality and a larger variety of products. Moreover, issues such as food safety and production conditions are major concerns for consumers nowadays. Apart from the changes in preferences of consumers, there are also structural changes in processing and retailing of agri-food products. Processors and retailers have become larger and more internationalized. Agricultural policies have undergone several changes at national and EU level as well, which have led to a decreasing level of market protection and to shifting priorities in spending public funds.

The development of more integrated supply chains was not followed by simultaneous development of supply-chain performance indicators and metrics in order to assess the effectiveness of a particular chain organization (Gunasekaran et al. 2001). This is not only true for agri-food chains, but reflects the general developments in this area. Measurement of supply-chain performance gives decision-makers inside (e.g. producers, distributors, marketers) and outside (e.g. policy-makers, investors) the supply-chain information for decision making, policy development, etc. The goal of this study is to develop a flexible conceptual framework for measuring the performance of agri-food supply chains that can be used by different decision-makers. The objectives of this paper are therefore:

- to provide a literature review on existing performance indicators in supply chains;
- to give an overview of different methods and models used to measure performance of supply chains;
- based on the literature review, to develop a conceptual framework on selection of performance indicators in agri-food supply chains.

PERFORMANCE INDICATORS IN SUPPLY CHAINS

In 1992 Lee and Billington found that no adequate supply-chain metrics exist, and firms, even if they are participating in coordinated supply chains, only aim at achieving their own performance standards. (Beamon 1999) looked at performance indicators used in supply-chain modelling and concluded that "current supply chain performance measurement systems are inadequate because they rely heavily on the use of cost as primary measure, they are not inclusive, they are often inconsistent with the strategic goals of the organization, and do not consider the effects of uncertainty". A few years later, Gunasekaran et al. (2001) reviewed the literature of performance metrics of supply chains again and concluded that there is still a lack of a balanced approach with regards to financial as well as non-financial indicators and the number of performance indicators to be used. Furthermore, no distinction is made between indicators of operational, tactical and strategic level. In their work Gunasekaran et al. (2001) develop a conceptual model for supply-chain performance at three levels: strategic, tactical and operational. There seems to be consensus about the fact that no supply-chain measurement system exists that is inclusive, universal and measurable as well as consistent (Beamon 1998). There is less agreement, however, on the matter of what such a system should look like. Hannus (1991)[1] emphasizes that a supply-chain measurement system should reflect the objectives of main interest groups (customers, owners and personnel), it should combine operational and financial follow-up data, and link operational objectives to critical success factors and goals. He suggests using three main categories of performance indicators: customer satisfaction, flexibility and efficiency, and to pay attention to three main indicators such as quality, time and costs in these main categories. In his paper he developed an approach for business-process re-engineering. This approach was lately described in the work of Korpela et al. (2002) as the basic theoretical framework in supply-chain development and combined with the theory of analytic hierarchy process (AHP). This paper was an attempt to demonstrate how the analytic hierarchy process can be used for supporting the supply-chain development process.

Murphy et al. (1996) conducted a two-stage study, where the first stage gave an overview of performance indicators and their dimensions used in literature from 1987 to 1993 and the second stage examined the relationship between performance variables and the existing performance dimensions. In their work Murphy et al. (1996) used 19 performance indicators, mostly being of financial nature such as net income or return on investments. In 1999, Beamon (1999) suggested a system of three dimensions: resources (i.e. efficiency of operations), output (i.e. high level of customer service) and flexibility (i.e. ability to respond to a changing environment). Persson and Olhager (2002) adhered to this three-dimension system. Based on results of a simulation model they concluded that good quality and short lead-times in integrated and synchronized supply chains lead to superior performance. The pay-off in terms of total cost is more than proportional to the improvements in quality and lead-times.

Li and O'Brien (1999) suggested a model to improve supply-chain efficiency and effectiveness based on four criteria: profit, lead-time performance, delivery promptness and waste elimination. Their model analyses the supply-chain performance at two levels: the chain level and the operational level. At the chain level, assumptions for these four criteria are set for each supply-chain stage so that the supply-chain performance can meet the customer service objectives. At the operations level, manufacturing and logistics procedures are optimized under the given objectives and three different strategies. The results of the model revealed that lead-time performance is the most influential factor for the choice of the strategy. Berry and Naim (1996) and later on Li and O'Brien (1999) emphasize that the efficiency of supply chains can generally be improved by reducing the number of manufacturing stages, reducing lead-times, working interactively rather than independently between stages and speeding up the information flow. Efficiency and effectiveness were also used in the work of Lai et al. (2002) to evaluate the supply-chain performance in transport logistics. Lai et al. identified three dimensions of supply-chain performance in transport logistics. Those dimensions are service effectiveness for shippers, operational efficiency and service effectiveness for consignees. Within these dimensions they identified four performance indicators such as responsiveness, reliability, costs and assets.

Van de Vorst (2000) distinguished several performance indicators for food supply chains on three levels: supply chain, organization and process. At supply-chain level five indicators are distinguished: product availability, quality, responsiveness, delivery reliability and total supply-chain costs. At organization level again five indicators are distinguished: inventory level, throughput time, responsiveness, delivery reliability and total organizational costs. Finally at process level four indicators are distinguished: responsiveness, throughput time, process yield and process costs. Thonemann and Bradley (2002) follow the line of Eppen (1979) and analyse the effect of product variety on supply-chain performance, measured in terms of expected lead-time and expected cost at the retailer level in a single-manufacturer and multiple-retailer model. They showed that underestimating the cost of product variety leads companies to offer product variety that is greater than optimal. The authors also demonstrate how supply-chain performance can be managed by reducing the set-up time, the unit-manufacturing time, the number of retailers or the demand rate.

In 2003 Claro et al. built an integrated framework for Dutch potted-plant and flower production that aimed at the combination of constructs on the transaction, dyadic and business-environment level for testing their impact on relational governance and performance. Each of these three levels consists of different determinants. Determinants of transaction level are exchange mode, human and physical transaction-specific assets, determinants of dyadic level are length of business interaction and organizational trust, and finally, determinants of business-environmental level are network intensity and environmental instability. As an indicator of relational governance they used joint planning and joint problem solving and as indicator of performance they used sales growth rate and perceived satisfaction. The results revealed that the dimensions of relational governance

Table 1. *Literature review on supply-chain performance measures*

Author	Sector	Customer responsiveness	Efficiency	Flexibility	Other	Number of indicators
Eppen (1979)	Steel production		X			1
Hannus (1991)[1]	Manufacturing		X	X		3
Lee and Billington (1992)	Manufacturing		X			1
Berry and Naim (1996)	Manufacturing	X		X	X	4
Murphy et al.(1996)	Different industries		X		X	35
Beamon (1998)	Manufacturing	X	X	X	X	16
Beamon (1999)	Manufacturing	X	X	X	X	33
Li and O'Brien (1999)	Manufacturing	X	X	X	X	11
Talluri et al. (1999)	Manufacturing	X	X		X	9
Van de Vorst (2000)	Food	X	X	X	X	8
Gunasekaran (2001)	Not specified	X	X	X	X	43
Thonemann and Bradley (2002)	Manufacturing	X	X			2
Korpela et al. (2002)	Not specified	X	X	X		3
Lai et al. (2002)	Transport	X	X	X	X	4
Talluri and Baker (2002)	Manufacturing	X	X	X	X	15
Persson and Olhager (2002)	Manufacturing	X	X	X	X	7
Claro et al. (2003)	Horticulture		X	X		2
Gunasekaran (2004)	Different industries	X	X	X	X	45

[1] The work of Hannus (in Finnish) is taken from the paper by Korpela et al. (2002)

positively affect sales growth and perceived satisfaction, except that joint planning is not related to perceived satisfaction.

The literature review shows that many attempts have been made to develop a measurement system for supply chains. None have been successfully incorporated in practice. Table 1 summarizes the papers described above in the most commonly used categorization: efficiency, flexibility and responsiveness. Responsiveness aims at a high level of customer service and may include fill rate, product lateness, customer response time, lead-time and shipping errors. Flexibility indicates the degree to which the supply chain can respond to a changing environment. Flexibility includes customer satisfaction and reductions in the number of backorders, lost sales and late orders. Efficiency aims to maximize value added by the process and minimize the cost absorbed in inventories. It includes several indicators, but the most commonly used are costs, profit, return on investment and inventory (inventory investments, inventory obsolescence).

As can be seen from Table 1 research on agri-food supply chains is rather limited. Furthermore, the literature review showed several performance indicators that could not be placed under one of the three categories and are therefore placed in a category 'other'. These performance indicators are, for instance, range of products and services, variations against budget, product differentiation, stock-out probability, etc.

MODELS AND METHODS TO ASSESS SUPPLY-CHAIN PERFORMANCE

Different methods exist that can incorporate multiple performance indicators into one measurement system. Some of the best-known are the Supply-Chain Council's Supply-Chain Operations Reference (SCOR®) model, the Balanced Scorecard, Multi-Criteria Analysis, Data-Envelopment Analysis, Life-Cycle Analysis, and Activity-Based Costing. The review in this section discusses different measurement methods and the advantages and disadvantages of these methods.

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 towards measuring the performance of an overall supply chain. The SCOR® model advocates a set of supply-chain performance indicators as a combination of: 1) reliability measures (e.g., fill rate, perfect order fulfilment); 2) cost measures (e.g., cost of goods sold); 3) responsiveness measures (e.g., order fulfilment 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 decomposes the processes within a supply chain and provides a best-practice view of supply-chain processes. The advantages of the SCOR® model are that it takes into account the performance of the overall supply chain; it proposes a balanced approach by describing performance of the supply chain in multiple dimensions. Disadvantages include the fact that SCOR® is very operations-oriented and does not attempt to describe all relevant business processes or activities such as sales and marketing, research and technology developments, product developments and post-delivery customer support. Secondly, and related tot the previous disadvantage, SCOR® assumes but does not explicitly address training, quality, information technology and administration (Supply-Chain Council 2004). Scientific research using the SCOR® model is limited. Based on the SCOR® model (developed by Stephens 2000) Lai et al. (2002) used the model to evaluate supply-chain performance. Lai et al. identified three dimensions of supply-chain performance in transport logistics, which are service effectiveness for shippers, operational efficiency, and service effectiveness for consignees. Based on these three dimensions a 26-item supply-chain performance measurement instrument was constructed, which was tested empirically and found to be reliable and valid for evaluating supply-chain performance in logistics. Wang (2003) related product characteristics to supply-chain strategy in order to analyse a product-driven supply-chain selection, and adopted SCOR® model level-1 performance metrics as the decision criteria for supplier selection. Based on the SCOR® model they developed an analytic hierarchy process (AHP) with overall objective to achieve optimal supplier efficiency. Then, authors developed an integrated multi-criteria decision-making methodology based on AHP and pre-emptive goal programming (PGP) so that it takes into account both qualitative and quantitative factors in supplier selection. They found that integrated AHP-PGP methodology can select the best set of multiple suppliers to satisfy suppliers' capacity constraint.

The Balanced Scorecard is a popular performance measurement scheme initially developed by Kaplan and Norton (1992). This method employs performance metrics from 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), 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 advantages of the Balanced Scorecard are that it uses four performance dimensions, both financial and non-financial, which ensures that management is given a balanced view on performance. Finally, a top-level strategy and middle-management level actions are clearly connected and appropriately focused. Disadvantages are that this approach requires considerable thoughts and effort to develop an appropriate scorecard, the scorecard does not include market-oriented performance indicators, and complete implementation should be staged (Coronel 1998). The Activity-Based Costing (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 based on these cost drivers, such as allocating overhead either equally or based on less-relevant cost drivers. This approach allows for better assessing the productivity and costs of a supply-chain process. By means of the ABC method companies can more accurately assess, e.g., the costs of services for a specific customer or the costs of marketing a specific product. Hence, businesses can 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 advantages of ABC are that it gives more than just financial information and it recognizes the changing cost behaviour of different activities as they grow and mature. Disadvantages are that ABC, like the Balanced Scorecard, is not developed for supply chains but could be adapted. Furthermore, data collection can be costly and time-consuming. While it is difficult to determine appropriate cost drivers in ABC for businesses, this may even prove to be a bigger challenge for supply chains. ABC focuses primarily on costs.

Traditional accounting is focused on short-term financial results like profits and revenues, providing little insight into the success of an enterprise towards generating long-term value to its shareholders. To overcome this problem, the estimation of a company's Economic Value-Added (EVA) was introduced. 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, basing it on 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 the supply-chain metrics within an executive-level performance scorecard, and can be included in other measurement systems such as, e.g, the Logistics Scoreboard approach (Lapide 2000). The advantages of EVA are that it explicitly considers the cost of capital and allows projects to be viewed separately. Disadvantages of EVA are its difficulties with computations and allocation of EVA among divisions.

Multi-Criteria Analysis (MCA) establishes preferences between options by reference to an explicit set of objectives that the decision-maker has identified, and for which he or she has established measurable criteria to assess the extent to which the objectives have been achieved. This method is designed to support decision-makers facing complex, multi-dimensional problems (Romero and Rehman 2003). Several techniques exist, like direct analysis of the performance matrix, multi-attribute utility theory, linear additive models, procedures that use qualitative data inputs and so on. The following steps are carried out by the decision-makers in MCA: 1) identify the feasible alternatives or preferred outcomes; 2) identify the criteria by which to judge these outcomes; 3) apply appropriate weights on each of the criteria that reflect their particular preferences.

One of the biggest advantages of MCA is that it facilitates a participatory approach to decision making. Another advantage is that the interactive nature of the approach enables both analyst and decision-maker to learn more about the problem. Finally, it is suitable for problems where monetary values of the effects are not readily available. On the other hand, although MCA does not necessarily require quantitative or monetary data, the information requirements to derive the weights can be considerable. Furthermore, despite the use of explicit weights in MCA, the analyst may unintentionally introduce implicit weights during the evaluation process that may lead to results that cannot be explained.

Life-Cycle Analysis (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 re-use 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 economic performance, when combined with the life-cycle cost-assessment method (Azapagic and Clift 1999; Hagelaar and Van der Vorst 2002; 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. The advantage of this method lies in the fact that LCA allows the establishment of comprehensive baselines of information on a product's or processor's resource requirement. Secondly, it allows identifying areas within a product's life cycle where the greatest reduction of environmental burdens can be achieved. LCA has two main disadvantages. First, it is a data-intensive methodology. Second, the proliferation of conflicting life-cycle analyses on the same products (environmental indexes assigned to each type of material can be influenced by the criteria and priority in developing the indices) are causing customers' confusion and a lack of confidence in the LCA methodology.

Hagelaar and van der Vorst (2002) used Life Cycle Assessment (LCA) to structure environmental supply chains. Their main objectives were: 1) to develop guidelines for managers of supply chains from an environmental perspective; 2) to relate a supply chain to its environmental performance; and 3) to assess the applicability of LCA as a tool for environmental supply-chain management. They concluded that if chains use LCA as a management instrument, they may have to adjust the chain structure to meet requirements set for the use of that instrument. In their paper they argue that in line with a differentiation between environmental-care chain strategies and environmental chain performances, a differentiation between types of LCA should be made, i.e., between compliance-process and market-oriented LCAs. To execute these different types of LCAs, the chain structure should be adjusted to meet the specific requirements of these types. They found that the choice of the type of LCA is conditional on factors external and internal to the chain such as competition, governmental laws, consumer preferences (external) and budget, knowledge, technology, cooperation (internal), etc. Thus the integration of different types of LCAs in the chain brings about a different chain structure.

Data Envelopment Analysis (DEA) measures the efficiency of a firm (chain) relative to the efficiency of competitors. The problem with respect to efficiency in supply chains is that beside direct outputs, which are delivered directly to the market, a firm also produces output that is input to a firm in the next stage. These intermediate outputs are intermediate inputs to the firm in the adjacent stage, next to the direct inputs. Contributions of Zhu (2003) in this field are a first step towards measuring supply-chain efficiency. The method allows inclusion of various

***Table 2**. Advantages and disadvantages of methods to assess supply-chain performance*

Methods	Advantages	Disadvantages
Activity-Based Costing (ABC)	• Gives more than just financial information • Recognizes the changing cost behaviour of different activities	• Costly data collection • Difficulties to collect initially required data • 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 difficulties • Difficult to allocate EVA among divisions
Multi-Criteria Analysis (MCA)	• A participatory approach to decision-making • Enables decision-maker to learn more about the problem • Suitable for problems where monetary values of the effects are not readily available	• Information requirements to derive the weights can be considerable • Possibility to introduce implicit weights leading to results that cannot be explained
Life-Cycle Analysis (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 the life cycle of a product or process	• Data-intensive methodology • Lack of confidence in the LCA methodology
Data-Envelopment Analysis (DEA)	• All inputs and outputs are included • Generates detailed information about the efficient firms within a sample • Does not require a parametric specification of a functional form	• Deterministic approach • Data-intensive
Supply-Chain Council's SCOR® Model	• Takes into account the performance of the overall supply chain • Balanced approach • Performance of the 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

dimensions, e.g. economic and environmental performance. The problem with measuring supply-chain efficiency using the DEA model is that it requires an enormous amount of data, while data gathering is one of the most complex issues in a supply-chain context. The advantages of DEA modelling are numerous. DEA takes a systems approach, which means that it takes into account the relationship between all inputs and outputs simultaneously. DEA generates detailed information about the efficient supply chain within a sample and which supply chains can be used as a benchmark. DEA does not require a parametric specification of a functional form to construct the frontier. Thus there is no need to impose unnecessary restrictions on the functional forms that very often become a cause of distorted efficiency measures. DEA has the disadvantage of being a deterministic approach, which implies that statistical noise may be confounded with inefficiency.

Talluri et al. (1999) studied the importance of a partner selection process in designing efficient value chains. They propose a two-stage framework, where the first stage involves identification of efficient candidates for each type of business process (manufacturing, distribution, etc.) using DEA and the second stage encompasses the use of an integer goal-programming model to select an effective combination of the efficient business processes. Talluri and Baker (2002) proposed a multi-phase mathematical programming approach for effective supply-chain design. They developed a combination of multi-criteria efficiency models based on game-theory concepts and linear integer-programming methods. The first phase evaluates suppliers, manufacturers and distributors in terms of their efficiencies with respect to input used and output generated. The model developed in this phase is a combination of a DEA model and a Pair-wise Efficiency Game (PEG). These methods generate an efficiency score for each candidate. The second phase includes the application of an integer-programming model, which optimally selects candidates for supply-chain network design by integrating efficiency scores from the first phase, demand and capacity requirements, and location constraint. The third phase identifies the optimal routing for all individuals in the network by solving a minimum-cost transhipment model.

It is clear from Table 2 that all described methods have their advantages and disadvantages. Therefore, there is a need to consider carefully all arguments for and against the selected method to measure supply-chain performance. It is also possible to combine two different methods to measure supply-chain performance. For instance, Balanced Scorecard can be combined with EVA, because the EVA method is project-focused, while Balanced Scorecard is functional-focused. Nevertheless, when using a combination of different performance measurement methods, great care needs to be taken to avoid conflicts between different performance matrices used to evaluate the performance of the chain in different dimensions.

AGRI-FOOD SUPPLY CHAIN

When developing a supply-chain measurement system it is imperative to consider the supply chain to be measured since it may have specific characteristics. In general two types of agri-food supply chains can be distinguished: 1) supply chains for fresh products such as fresh vegetables, flowers and fruit; 2) supply chains for processed food products such as canned food products, dessert products, etc. This research is focused on supply chains for fresh agricultural products, more specifically on vegetable supply chains. These supply chains consist of growers, auctions, wholesalers, importers and exporters, and retailers. The main processes are producing, storing, packing, transportation and trading of these products. These supply chains have many specifications, which set them apart from other types of supply chains. Several authors (Van der Vorst 2000; Van der Spiegel 2004) have summarized the following specific aspects of agri-food supply chains:

1. shelf-life constraints for raw materials and perishability of products, intermediates and finished products, and changes in product quality level while progressing through the supply chain (decay);
2. long production throughput time (production of new or additional products requires a long time);
3. seasonality in production;
4. seasonal supply of products requires global sourcing;
5. conditioned transportation and storage required;
6. variable process yield in quantity and quality due to biological variations, seasonality, factors connected with weather, pests and other biological hazards;
7. storage-buffer capacity restrictions, when materials or products can only be kept in special containers;
8. governmental rules concerning environmental and consumer-related issues (CO_2 emission, food-safety issues);
9. physical product features like sensory properties such as taste, odour, appearance, colour, size and image;
10. additional features: e.g. convenience of ready-to-eat meal;
11. product safety: increased consumer attention concerning both product and method of production: no risks for the consumer of foods are allowed;
12. perceived quality, also relevant for food applications: e.g., advertisement or brands (marketing) can have a considerable influence on quality perception.

Recent socioeconomic developments have resulted in a change in performance requirements for food supply chains as a whole and for all stages in the supply chain (Van der Vorst 2000). This change is the outcome of the variation in buying behaviour of consumers. Consumer preferences have become the major determinant of quality and production methods. Food safety and human health are important social concerns, particularly when it comes to greenhouse vegetables (Buurma 2001). Consequently, demand for fresher products and products with higher added values increases. The use of pesticides and other chemicals negatively affects consumers' buying behaviour. Consequently, consumers have high demands on a broad range of quality aspects like food safety, production characteristics, sensory properties, shelf life, reliability, convenience, availability and quality/price ratio (Van der Spiegel 2004). The risks associated with poor quality (e.g. outbreaks of animal diseases and low food safety) are so high that retailers and consumers claim to be increasingly prepared to pay more for higher quality (Van der Vorst et al. 2001). Nonetheless, 'price wars' in supermarkets that are vying for consumers' loyalty and international competition are putting pressure on prices. Furthermore, regardless of all the demands for specific attributes, many consumers around the world remain price buyers.

Agri-food supply chains are very sensitive to policy changes concerning the environmental issues. During the past 7-10 years, in The Netherlands public concerns arose about the production system for greenhouse vegetables (Buurma 2001). These concerns were associated with pollution, industrial processes and bulk production. The government took responsibility and covenants were concluded to reduce the use of pesticides and energy by 50%. Besides the consumers' preference variation, environment plays a crucial role in agri-food supply-chain performance assessment, because agricultural products are strongly influenced by nature. The environmental variability (e.g. weather conditions) can be reflected in the quantity and the quality of the farm products. The perishability of fresh products such as fruits and vegetables put strains on logistics and quality management. Given these facts we can say that food quality and environmental issues have a great impact on agri-food supply-chain performance. Thus, based on the specifications of agri-food production, when developing a performance measurement system for agri-food supply chains, the indicators that reflect the quality aspects of products and processes are highly relevant (freshness, food safety, environmental issues, etc.) and together with other financial and non-financial indicators, included into one performance measurement system.

Quality is difficult to define and therefore difficult to measure. The quality indicators of a product in literature are often divided into intrinsic and extrinsic quality attributes (Jongen 2000; Luning et al. 2002; Tijskens 2004) or similarly into product and process quality indicators (Northen 2000). For years, performance of production systems has commonly been evaluated by measuring costs or by measuring the intrinsic product quality such as product safety and sensory properties (taste, colour, texture) (Van der Spiegel 2004). Quality is a multidimensional construct that is based on both perceived intrinsic and extrinsic quality attributes available in the shop (Acebron and Dopico 2000). This means that a buying decision is based on more than only intrinsic properties of a product; extrinsic properties also play a role.

Intrinsic quality indicators refer to physical properties such as flavour, texture, appearance, shelf life and nutritional value. The properties are directly measurable and objective. Quality is formed by turning physical properties of a product into quality attributes by the perception of the consumer (Jongen 2000). The intrinsic product properties define the state of the product, which is evaluated with respect to quality criteria imposed by a producer or user (Sloof et al. 1996).

Extrinsic quality attributes refer to the production system and include factors such as the amount of pesticides used, type of packaging material, use of biotechnology (Jongen 2000). Extrinsic factors do not necessarily have a direct influence on physical properties but influence the acceptance of the product for consumers. The total of intrinsic and extrinsic factors determines the purchase behaviour (Jongen 2000).

In this study we follow the division according to the division into intrinsic (product) and extrinsic (process) quality indicators by Luning et al. (2002). In their work, Luning et al. have divided product quality into 3 aspects: 1) food safety and health; 2) sensory properties and shelf life; 3) product reliability and convenience. Process quality also consists of 3 aspects: 1) production system characteristics; 2) environmental aspects; 3) marketing. Within product safety and health, health refers to food composition and diet. Food safety refers to the requirement that products must be 'free' of hazards with an acceptable risk. The sensory perception of food is determined by the overall sensation of taste, odour, colour, appearance, texture and sound, which are determined by physical features and chemical composition. The shelf life of a product can be defined as the time between harvesting or processing and packaging of the product and the point at which it becomes unacceptable for consumption. Product reliability refers to the compliance of actual product composition with product description, and convenience relates to the ease of use or consumption of the product for the consumer (Luning et al. 2002). Production system characteristics refer to the way a food product is manufactured and includes factors such as pesticides used, animal welfare and use of genetic engineering. Environmental implications of agri-food products refer mainly to the use of packaging and food waste management. Marketing efforts determine quality attributes, affecting quality expectation. Process specifications include the type of equipment needed and handling conditions required. Jongen (2000) and Northen (2000) name traceability and organic production as examples of process indicators.

DEVELOPING A CONCEPTUAL FRAMEWORK

Based on the literature review on existing performance indicators and taking into account the theoretical frameworks underlying the different methods and models such as SCOR® model and/or Balanced Scorecard, the conceptual framework has been developed. The framework takes into consideration specific characteristics of agri-food supply chains. For this purpose, the agri-food supply-chain performance indicators are grouped in four main categories: efficiency, flexibility, responsiveness and food quality. The categories efficiency, flexibility and responsiveness are chosen based on Table 1. These main categories contain more detailed performance indicators. Based on the framework of food quality developed by Luning et al. (2002), the specifications of agri-food supply chains are grouped under the category 'food quality'. Adding the category 'food quality' to the three other categories derived from the literature review results in a complete conceptual framework for measuring the performance of agri-food supply chains (Figure 1).

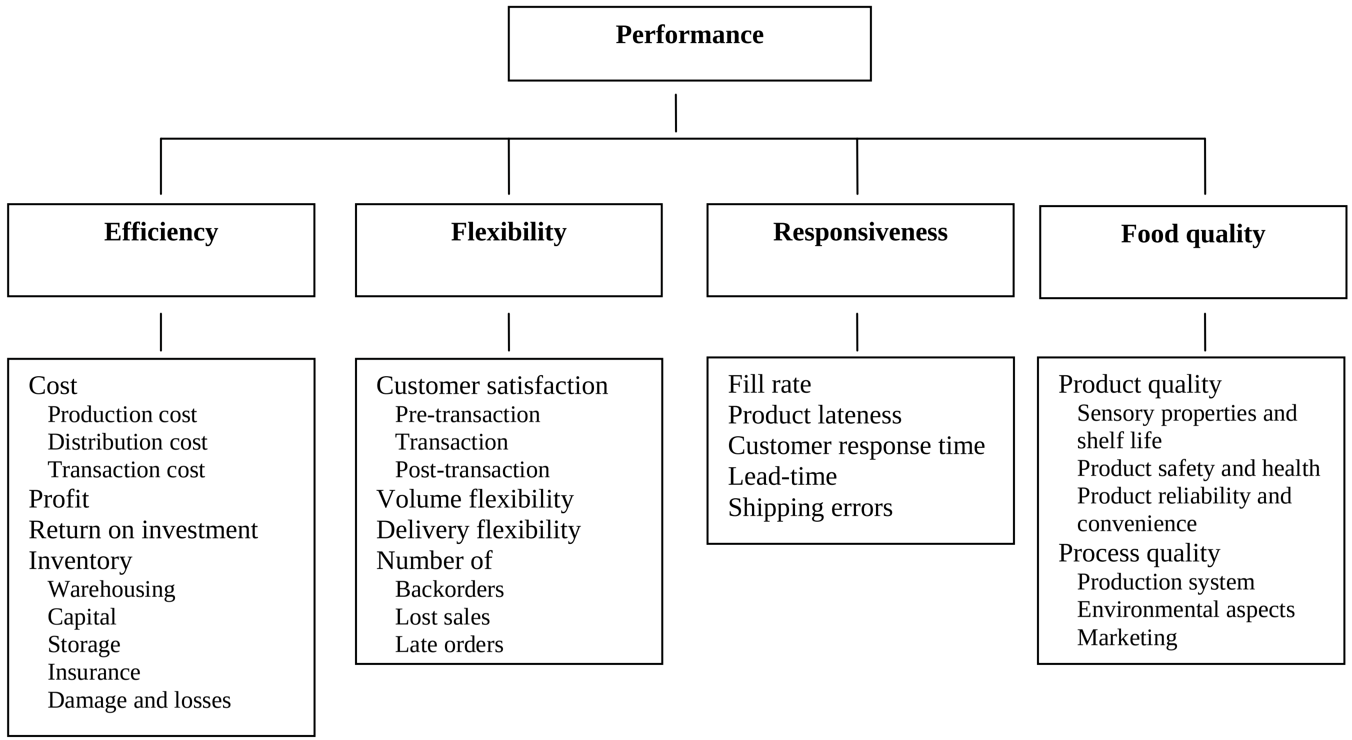

Figure 1*. Conceptual framework of agri-food supply-chain performance indicators*

FUTURE OUTLOOK

This paper reviewed the available supply-chain performance indicators and models and methods used to asses the performance of supply chains. Based on the existing body of research in supply-chain performance measurement systems a research framework has been suggested for measuring the performance of agri-food supply chains. The suggested framework is based on a literature review and needs to be tested empirically. In future research this conceptual framework will be tested by interviewing the experts (managers) and stakeholders across the entire agri-food supply chain. During the interviews experts will be asked to judge the feasibility and the measurability of suggested indicators. Experts will be given the opportunities to suggest new indicators and to reject the proposed ones and to provide suggestions for better (practically possible) ways to measure the suggested indicators. This procedure should be provided with sufficient argumentation. Based on the results of interviews the final research framework for measuring the performance of the agri-food supply chain will be developed that will meet criteria of inclusiveness, universality, measurability and consistency.

NOTES

[1] The work of Hannus (in Finnish) is taken from the paper by Korpela et al. (2002)

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