CHAPTER 2

PERFORMANCE MEASUREMENT IN AGRI-FOOD SUPPLY-CHAIN NETWORKS

An overview

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Abstract. Many researchers and practitioners are working on the enhancement of supply-chain collaboration in order to improve performance of the individual supply-chain members and supply-chain performance as a whole. Performance measurement fulfils a crucial role in the development of supply chains as it can direct the design and management of the chain towards the required performance. It is the key instrument to discuss and evaluate the effectiveness of (potential) chain partnerships. This paper presents a framework for the development of innovative food supply-chain networks and discusses the implications for performance measurement systems. Current bottlenecks and research opportunities are presented.
Keywords: performance indicators; network optimization; (bottlenecks and) research opportunities

INTRODUCTION

The importance of performance measurement has long been recognized. Manufacturing and management consultant Oliver Wright almost 30 years ago offered the oft-repeated saying, "You get what you inspect, not what you expect" (Melnyk et al. 2004). Metrics are therefore needed to evaluate how work is done and to direct the activities, since what we measure indicates how we intend to deliver value to our customers. Incorrect performance measurement systems (PMS) can create disincentives and unwanted behaviour.

The number of publications on performance measurement has increased significantly in the last decade (e.g. Beamon 1999; Lohman et al. 2004; Gunasekaran et al. 2004). This is mainly because of a number of fundamental changes in the business environment, especially in agri-food chains. Consumers in Western-European markets have become more demanding and place new demands on attributes of food such as quality (guarantees), integrity, safety, diversity and associated information (services). Demand and supply are no longer restricted to

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nations or regions but have become international processes. We see an increasing concentration in agribusiness sectors, an enormous increase in cross-border flows of livestock and food products and the creation of international forms of cooperation. The food industry is becoming an interconnected system with a large variety of complex relationships, reflected in the market place by the formation of (virtual) Food Supply Chain Networks (FSCNs) via alliances, horizontal and vertical cooperation, forward and backward integration in the supply chain and continuous innovation (Beulens et al. 2004). The latter encompass the development and implementation of enhanced quality, logistics and information systems that enable more efficient execution of processes and more frequent exchange of huge amounts of information for coordination purposes (Van der Vorst et al. 2005). All these developments initiate a reorientation of companies in Dutch agriculture and food industry on their roles, activities and strategies. As a consequence also the PMS need adjustments as traditional measurement approaches may limit the possibilities to optimize the FSC(N) as a whole.

This paper presents an overview of performance measurement in agri-food supply-chain networks. We will first go deeper into the concept of FSCN. Next, we will discuss a framework for chain/network development that will be used to derive requirements for PMS. We will discuss bottlenecks of performance measurement in FSCN and conclude with an overview of research opportunities in this area.

FOOD-SUPPLY-CHAIN NETWORKS

Supply-chain management (SCM) is the integrated planning, coordination and control of all business processes and activities in the supply chain to deliver superior consumer value at least cost to the supply chain as a whole while satisfying the variable requirements of other stakeholders in the supply chain (e.g. government and NGOs) (Van der Vorst 2000). In this definition a *supply chain* is a series of (physical and decision-making) activities connected by material and information flows and associated flows of money and property rights that cross organizational boundaries. The supply chain not only includes the manufacturer and its suppliers, but also (depending on the logistics flows) transporters, warehouses, retailers, service organizations and consumers themselves. In the definition of SCM a *business process* refers to a structured, measured set of activities designed to produce a specified output for a particular customer or market (Davenport 1993). Next to the logistical processes in the supply chain (such as operations and distribution) we distinguish business processes such as new-product development, marketing, finance, and customer relationship management (Chopra and Meindl 2001). Finally, *value* is first of all the amount consumers are willing to pay for what a company provides and it is measured by total revenue. The concept ‘value-added activity’ originates from Porter’s ‘value chain’ framework and characterizes the value created by an activity in relation to the cost of executing it (Porter 1985). Currently the value concept is more expanded. We now talk about values associated with the so-called ‘Triple P’: People, Planet and Profit. So, next to financial performance also social and environmental performance are incorporated. These

latter two lead to (qualitative) attributes that are generally spoken associated with the product itself (biologically produced), the companies producing it (social policy) and the raw materials (GMO?) and resources (child labour?) used.

Figure 1 depicts a generic supply chain at the organization level within the context of a complete supply-chain network. Each firm is positioned in a network layer and belongs to at least one supply chain: i.e. it usually has multiple (varying) suppliers and customers at the same time and over time. Other actors in the network influence the performance of the chain. As Håkånsson and Snehota (1995) state: "what happens between two companies does not solely depend on the two parties involved, but on what is going on in a number of other relationships". Therefore, the analysis of a supply chain should preferably take place or be evaluated within the context of the complex network of food chains, in other words a Food Supply Chain Network (FSCN). Lazzarini refers to a 'netchain' and defines it as "a directed network of actors who cooperate to bring a product to customers" (Lazzarini et al. 2001).

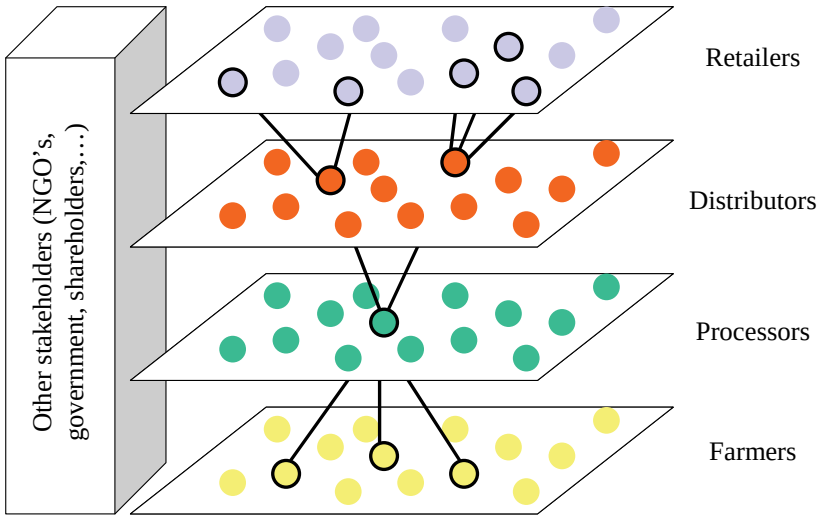

***Figure 1**. Schematic diagram of a supply chain from the perspective of the processor (bold flows) within the total FSCN (based on Lazzarini et al. 2001)*

In an FSCN different companies collaborate strategically in one or more areas while preserving their own identity and autonomy. As stated, in an FSCN more than one supply chain and more than one business process can be identified, both parallel and sequential in time. As a result, organizations may play different roles in different chain settings and therefore collaborate with differing chain partners, who may be their competitors in other chain settings. In brief, chain actors may be involved in different supply chains in different FSCNs, participate in a variety of business processes that change over time and in which dynamically changing

vertical and horizontal partnerships are required. This puts stringent requirements on the PMS as we will discuss later.

FRAMEWORK FOR CHAIN/NETWORK DEVELOPMENT

When researchers and/or managers discuss the potentials of chain and network development, there is a need for a 'language', a framework, that will allow us to describe supply chains, its participants, processes, products, resources and management, relationships between these and (types of) attributes of these in order to allow us to understand each other unambiguously (to a large extent). This section presents such a framework (Van der Vorst et al. 2005).

In an FSCN a number of typical characteristics can be identified. In line with the thoughts of Lambert and Cooper (2000) we distinguish the following four elements that can be used to describe, analyse and/or develop a specific (supply chain within the) FSCN (see Figure 2):

1. The *Network Structure* demarcates the boundaries of the supply-chain network and describes the main participants or actors of the network, accepted and/or certified roles performed by them and all the configuration and institutional arrangements that constitute the network. The key is to sort out which members are critical to the success of the company and the supply chain – in line with the supply-chain objectives – and, thus, should be allocated managerial attention and resources.
2. *Chain Business Processes* are structured, measured sets of business activities designed to produce a specified output (consisting of types of physical products, services and information) for a particular customer or market. As stated before, next to the logistical processes in the supply chain (such as operations and distribution) we distinguish business processes such as new-product development, marketing, finance, and customer relationship management.
3. *Network and Chain Management* typifies the coordination and management structures in the network that facilitate the instantiation and execution of processes by actors in the network, making use of the chain resources with the objective to realize the performance objectives formulated by the FSCN. Lambert and Cooper (2000) distinguish two groups of management components (see Table 1). Especially the managerial and behavioural components are well-known obstacles to SCM as they might hinder the development of trust, commitment and openness between supply chain members.
4. *Chain Resources* are used to produce the product and deliver it to the customer (so-called transforming resources). These enablers include people, machines and ICT (information, information systems and information infrastructures).

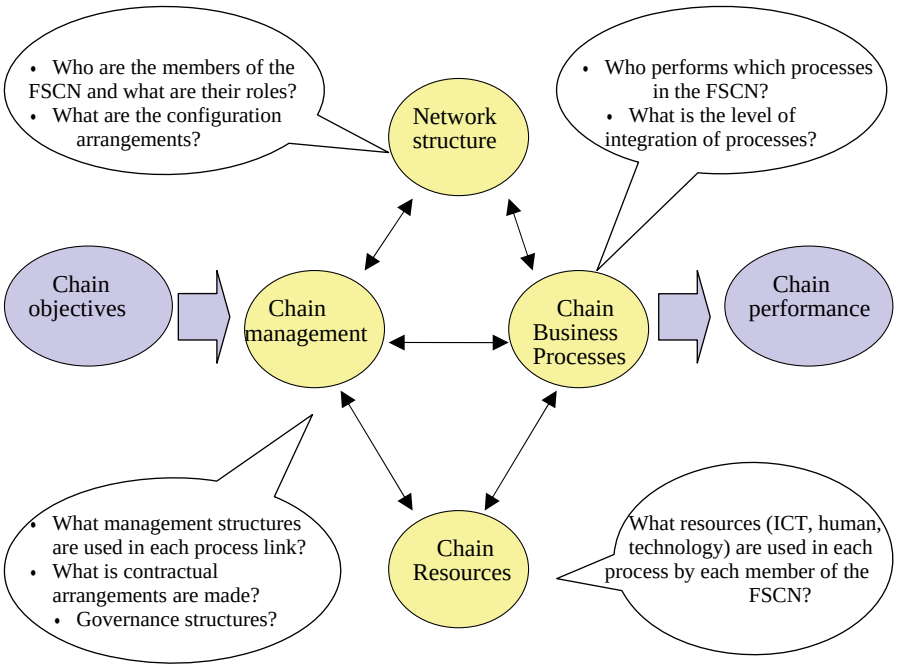

Figure 2. *Framework for chain/network development (adapted from Lambert and Cooper 2000)*

Table 1*. Two groups of management components that have to be aligned in the supply chain*

Physical and technical components	**Managerial and behavioural components**
• planning and control methods (e.g. push or pull control) • work flow/activity structure (indicates how the firm performs its tasks and activities) • organization structure (indicates who performs the tasks and activities, e.g. cross-functional teams) • communication and information flow facility structure (e.g. information transparency) • product flow facility structure (e.g. location of inventories, decoupling points)	• management methods (i.e. the corporate philosophy and management techniques) • corporate culture and attitude • risk and reward structure • power and leadership structure

In brief, within an FSCN we identify one or more Chain Business Processes with well-identified products that are produced and delivered to the customer of that Chain Business Process (e.g. chain processes that produce and deliver boxes with yoghurt or cheese slices to retail outlets). These production and delivery processes require the execution of *business activities* by one of the actors participating in the network (such as transportation, storing, order picking). There are precedence relations between business activities that are or may be determined by goods, resources, information, financial and control flows. So we may regard an FSCN as a directed network of business processes and activities with precedence relationships.

Each element of the framework is directly related to the *objectives of the FSCN*. One can focus on three generic value propositions, which can be found separately or in combination:

1. Network differentiation and market segmentation where the target is to differentiate as a chain to meet the specific demands of customers (e.g. assortment, product quality, etc.).
2. Integrated quality; the target here is to meet the increasing demand of consumers, governments, NGOs and business partners for safe and environmentally friendly produced products.
3. Network optimization; the target here is cost reduction through a streamlined and efficient chain/network with rational information supply.

Whether these objectives are realized in practice can be measured via output performance of the supply chain (network). Supply-chain performance is defined as the degree to which a supply chain fulfils end-user and stakeholder requirements concerning the relevant performance indicators at any point in time. *Performance indicators* (or performance metrics) are operationalized process characteristics, which compare the performance of a system with a norm or target value. Or, as Christopher (1998) states, “they refer to a relatively small number of critical dimensions which contribute more than proportionally to the success or failure in the marketplace”. It depends on the objectives of the supply chain as to which specific *key performance indicators* (KPIs) are appropriate and used.

The groundwork for successful SCM is established by an explicit definition of supply-chain objectives and related KPIs and, successively, by deciding on the four key elements of the FSCN. The optimal design will differ for each supply chain depending on the competitive strategy and the market, product and production characteristics.

IMPLICATIONS FOR PERFORMANCE MEASUREMENT

Performance measurement aims to support the setting of objectives, evaluating performance, and determining future courses of action on a strategic, tactical and operational level. To meet objectives, the output of processes must be measured and compared with a set of standards. In order to be controlled, the process parameter values need to be kept within a set limit and remain relatively constant. This will allow comparison of planned and actual parameter values and taking certain reactive

measures in order to improve the performance or re-align the monitored value to the defined value (Gunasekaran et al. 2004).

Since a supply chain is by its definition a collection of multiple actors with each their own specific objectives (and values and norms) a lot of effort has to be put in the development of a shared language, shared objectives, shared KPIs, etc. A well-defined set of chain performance indicators will help establish benchmarks and assess changes over time; but only when all stages in the supply chain aim to realize the same jointly defined objectives. As we have described the agri-food industry is becoming an interconnected system with an even larger variety of complex relationships reflected in the market place by the dynamic formation of chain partnerships. Chain actors may be involved in different supply chains and participate in a variety of business processes that change over time and in which dynamically changing vertical and horizontal partnerships are required. This places very specific (and dynamic) requirements on the PMSs of such companies, requiring high flexibility and possibilities for making integral analyses.

The supply-chain performance is an overall performance measure that depends on the performances of the individual chain stages and the respective processes that are executed in those stages. Processes can necessarily be identified at different levels of abstraction. That means that each process can be broken down into a directed and connected network of (sub-)processes/activities. As a consequence one makes a conscious choice of the abstraction level needed in the business context. As an example, (Van der Vorst 2000) presents a framework of logistics performance indicators that is divided into three hierarchical decision levels, namely the supply-chain performance, the performance of an individual organization and the performance of an individual business process (Table 2). All indicators are composites of, and dependent on, lower-level measures. For example, the supply-chain lead time and product quality are dependent on the throughput times of business processes in all chain/network stages.

While traditional PMSs are based on costing and accounting systems, measuring performance in supply-chain networks requires a more balanced set of financial and non-financial measures at various points along the supply chain (Lohman et al. 2004). A relevant development is the balanced-scorecard approach, which includes these additional performance sets (Kaplan and Norton 1992). But more development is needed. Next to traditional performance indicators such as costs, throughput time or technical quality of products also other indicators in line with the ‘Triple P’ philosophy (People, Planet, Profit) have to play a role in this process and should therefore be developed; examples are ‘guaranteed product integrity’, ‘environmental chain profile’ or ‘profile of animal-friendliness’ and ‘guaranteed quality, hygiene and safety’ in meat-producing chains. As stated, the chain/network objectives should play a directive role in this selection and definition process.

Table 2. *Example of Logistic KPIs for food-chain networks on three hierarchical levels (van der Vorst, 2000)*

Level	**Performance indicator**	**Explanation**
Supply-chain network	Product availability on shelf	Presence of a large assortment and no stock-outs
	Product quality	Remaining product shelf life
	Responsiveness	Order cycle time of the SC
	Delivery reliability	Meeting guaranteed delivery times
	Total SC cost	Sum of all organizations' costs in the supply chain
Organization	Inventory level	Number of products in store
	Throughput time	Time needed to perform chain of business processes
	Responsiveness	Flexibility of the organization: lead time
	Delivery reliability	% Orders delivered on time and in right quantity
	Total organization's cost	Sum of all process costs in the specific organization
Process	Responsiveness	Flexibility of the process
	Throughput time	Time needed to perform the process
	Process yield	Outcome of the process
	Process cost	Cost made when executing the process

There is a need to define and measure performance for each instantiation of the supply-chain network as a whole and to the level of the participating organizations and executed processes. Therefore, in line with the framework presented in the previous section, the set up of the PMS requires the identification of:

- A balanced number of performance metrics at multiple aggregation levels departing with the network objectives to capture the essence of the chain and organizational performance (Gunasekaran et al. 2004). This means taking into account:
  - indicators for the *chain network structure* to benchmark the objectives of each member. Is the chain/network to be evaluated on environmental issues or just financial performance? Examples of indicators are the contribution of each member in the total added value, ROI, etc.;
  - indicators for the output of the relevant *chain business processes* and *chain management structure* to assess the efficiency and effectiveness of the planning and control activities (e.g. logistics metrics such as lead time, responsiveness, inventory levels, delivery reliability, product quality, etc.);

  - indicators at process level related to *chain resources* utilization (e.g. process yield, utilization degree), well-being (humans) and perseverance (fit for the future).
- Dynamic metrics that recognize and respond to changes in customer requirements, operating inputs, resources and performance over time, and identify and anticipate to potential problems proactively;
- Metrics that fulfil the well-known evaluation criteria, such as validity (accurateness), robustness (similar interpretation by all users, repeatable, comparable across time and place), usefulness (understandable, benchmarkable and providing a guide for action), economy (cost–benefit evaluation of collecting and analysing the data), inclusiveness (measurement of all pertinent aspects), verifiable (based on an agreed upon set of data and a well-understood and well-documented process for converting these data into the measure) and consistency (measures consistent with organizational goals) (a.o. Melnyk et al. 2004; Beamon 1999; Caplice and Sheffi 1994).

BOTTLENECKS OF, AND DEVELOPMENTS IN PERFORMANCE MEASUREMENT

There is a need to define and measure performance for the supply chain as a whole and to be able to drill down to different measures and different levels of detail, in order to understand the causes of significant deviations of actual performance from planned performance (Lohman et al. 2004). However, many companies seem to be facing serious difficulties in developing and implementing such supply-chain-wide PMSs that capture various dimensions of performance at various levels in a consistent way. This was confirmed in a recent international study on traceability systems in agri-food supply chains where we found a general lack of chain cooperation and transparency (Van der Vorst 2004). Let's take a closer look at some of the bottlenecks:

- There is often a history of decentralized reporting with a focus on local operational use within factories, distribution centres, etc. This has led to an uncontrolled growth of reports with many inconsistencies, which have to do with definitions of performance metrics, sources of data for obtaining measures, and ways of presenting reports (Lohman et al. 2004). These local metrics, data gathering and reporting structures hinder an integrated analysis.
- There is a lack of standard definitions of KPIs and measurement methods. When companies start working in a supply-chain concept they often speak a different language; their objectives and definitions of KPIs are not harmonized. This is also due to the divergence in value propositions in the FSCN (note that practically each supply-chain member does business with multiple suppliers and customers).
- There is divergence in development stages of organizations. Some organizations lack internal integration and still have functional silos that do not cooperate. Furthermore, some have very sophisticated electronic information infrastructures whilst others have huge paper archives (divergence in ICT development phases).

Companies use many information systems that are linked in some way. The dispersed IT infrastructure produces a number of issues (Lohman et al. 2004):

- it adds to the lack of data integrity between the reports. Since considerable overlap exists between the systems, certain data can be extracted from multiple sources and this often leads to inconsistency;
- the infrastructure does not provide visibility over the supply chain, owing to the absence of connectivity;
- certain systems are not designed for reporting uses or cannot provide data at reasonable cost at all.

More and more multinationals practice benchmarking of production and sales units and have developed scorecards. Lately, more work is done on the standardization of performance metrics and PMS. For example, the Supply-Chain Council developed the Supply Chain Operations Reference (SCOR) model; a process reference model developed as the cross-industry standard diagnostic tool for SCM based on the basic processes 'Plan, Source, Make, and Deliver'. KPIs within SCOR focus on supply-chain delivery reliability, responsiveness, flexibility, costs and asset management. However, often a scorecard tailored to the needs of the specific company, chain or network is needed. Lohman et al. (2004) emphasize that the development of a PMS should be considered a co-ordination effort rather than a design effort. They suggest the development of a metrics dictionary using the metrics definition template presented in Table 3 as the main element in the.

***Table 3**. Performance metrics definition template (Lohman et al. 2004)*

Metric attribute	Explanation
Name	Use exact names to avoid ambiguity
Objective	The relation of the metric with the organizational objectives must be clear
Scope	States the area of business or parts of the organization that are included
Target	Benchmarks must be determined in order to monitor progress
Equation	The exact calculation of the metric must be known
Units of measure	What is/are the unit(s) used
Frequency	The frequency of recording and reporting of the metric
Data source	The exact data sources involved in calculating a metric value
Owner	The responsible person for collecting data and reporting the metric
Drivers	Factors that influence the performance, i.e., organization units, events, etc.
Comments	Outstanding issues regarding the metric

development of a PMS. Preferably, this development departs with existing reports at various levels in the organization(s) to understand current metrics in detail, to

identify shortcomings, and to include ongoing initiatives that affect PM (such as new information systems, etc.). The method will develop metrics in a consistent way and identify gaps in the current selection of metrics when confronted with the organizational objectives.

RESEARCH OPPORTUNITIES IN PERFORMANCE MEASUREMENT IN FSCN

Melnyk et al. (2004) point out that the topic of metrics as discussed by managers differs from the topic of measurement as typically discussed by academics. This is because academics are concerned with defining, adapting and validating measures that can be generalized to address specific research questions, whereas managers are generally more than willing to use a 'good enough' measure if it can provide useful information quickly. But when is the measure good enough?

Each FSC(N) requires its own PMS depending on the strategy and the FSC(N) characteristics. There is a need for the development of a balanced (dynamic) set of financial and non-financial FSCN performance indicators that reflect the interdependencies of different areas at the right aggregation level. There is a need for standard definitions of performance indicators to allow for integral analyses in dynamic configurations of FSCN. New KPIs are needed on different aggregation levels, because "PI's wear out as a result of their successful use as people adapt to the way they find themselves being measured and evaluated" (also known as the Hawthorn effect). Other research questions for the near future are:

- What metric set is suitable for the four levels in the framework for chain development?
- Should all metrics be mathematically derived or is there room for qualitative metrics?
- How should one make the trade-off between financial metrics and non-financial metrics?
- What environmental and social performance metrics can be developed that meet the requirements of the consumer?
- What is the optimal size of a metric set and how does one derive a predictive metric set?
- If one is to obtain proactive control, what predictive metric set (financial/non-financial) is suitable for what situation?
- How can we model in a generic way the dynamic configurations and performances of FSCN that concern more links and incorporate the requirements of all stakeholders in the FSCN? What quantitative method or technique is applicable? (see, e.g., Kleijnen and Smits 2003)
- How can we make these modelling methods comprehensible for managers so that the outcomes will be accepted?

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