Information Reference Models for European Pork Supply Networks – Identifying Gaps in Information Infrastructures –

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Abstract: Several global developments such as diminishing production resources, limits in the availability of water and the growing demand for bio-energy as well as sector-wide crises (e.g. BSE, swine fever, dioxin) have led to a changing attitude of society towards the consequences of the food system's activities for social, economic and environmental issues, captured in the term of sustainability. As a consequence, consumers show increasing interest in the characteristics of food, and in turn, on the availability of related information and guarantees. The paper introduces different information reference models for European pork supply networks, which give an aggregated overview about information availability and exchange in the pork sector, identify additional information demands of decision makers at different stages of pork production, and identify gaps in the existing information infrastructure. The models support different parties involved in pork production, such as enterprises, system developers and consultants, in developing enterprise or network specific solutions.

Keywords: *Information Modelling; Reference Modelling; Food Safety; Quality; Global Warming Potential*

1 Introduction

Several global developments such as diminishing production resources, limits in the availability of water and the growing demand for bio-energy (Standing Committee on Agricultural Research, 2007) as well as sector-wide crises caused by animal diseases (e.g. BSE, swine fever, foot-and-mouth disease, avian influenza) or food contaminations (e.g. dioxin, nitrofen; Bredahl et al., 2001; Van Dorp, 2004; Van Plaggenhoef et al., 2007) have led to a changing attitude of society towards the consequences of the agri-food system's activities for social, economic and environmental issues, captured in the term of sustainability (Aiking and de Boer, 2004; Fritz and Schiefer, 2008). As a consequence, consumers, and especially those in countries with abundance of food, show increasing interest in the characteristics of food, such as origin, safety, quality or the environmental impact of its production, and in turn, on the availability of related information and guarantees (Schiefer, 2002; Beulens et al., 2005; Codron et al., 2005; Van der Vorst et al., 2005; Verbeke, 2005; Trienekens and Zuurbier, 2008).

Enterprises in agri-food supply networks are facing new expectations and are seeking to communicate economic, social and environmental performance of their business to customers within the supply network and consumers as the final customers (French, 2008). Therefore not only solutions for serving the inter-enterprise information demands are needed, but also solutions which contribute to bridging the gap that has grown between agri-food production and the consumer due to production's decreased visibility and comprehensibility

(Dagevos and Bunte, 2009). Enterprises along supply networks as well as consumers demand transparency on different aspects of sustainability (Fritz and Schiefer, 2009), which implies a shared understanding of, and access to, product and process related information that they request, without loss, noise, delay and distortion (Hofstede, 2003). New developments in sustainability communication between retail and consumers like "food miles", "carbon footprints" and similar indicators reflect some of these developments (Fritz and Schiefer, 2008; Viatte, 2009).

The most well-adopted and most often quoted definition of the term sustainability is that of the Brundtland Commission, generally known as the Brundtland Report. It refers to sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (World Commission on Environment and Development, 1987). However, because the definition of sustainability is so far reaching, enterprises often find it difficult to determine their individual roles within this broad perspective (Shrivastava, 1995; Stead and Stead, 1996; Kramer and Meeusen, 2003). Enterprises have problems to identify future versus present needs, to determine technologies and resources required to meet those needs and to understand how to effectively balance organisational responsibilities to multiple stakeholders such as employees or other enterprises in the supply network and broader stakeholders including society (Hart, 1995; Starik and Rands, 1995).
In a competitive environment, in which integrated responsibilities for people, planet and profit (the "Triple P") are becoming a prerequisite for good entrepreneurship (Kramer and Meeusen, 2003; Savitz and Weber, 2006), consideration of these integrated views and provision of related information have already become an important competitive factor and are critical success factors for the agri-food sector's long-term success (Kinsey, 2001; Krieger et al., 2007; Wognum et al., 2010). However, the complexity for enterprises is apparent in the variety of indicators that are discussed regarding sustainability of the sector and its actors (Ondersteijn et al., 2006).

New solutions for determination and communication of sustainability, either in a broader sense, covering social, economic and environmental issues, or more narrowly, covering only single aspects of sustainability, are needed for agri-food supply networks (Schiefer, 2002; Ten Pierick and Meeusen, 2004; Van der Vorst et al., 2005). However, these solutions should preferably build on information that is already available (Kramer and Meeusen, 2003) and should provide flexible, cost- and time-saving solutions for enterprises to measure and evaluate sustainability of products throughout a supply network. Gained information on product characteristics might be used for decision support within enterprises as well as for communication of sustainable practices to customers and the consumer, resulting in increased competitiveness of enterprises, supply networks and the sector by satisfying customers' and consumers' need for information on the sustainability of a product.

Enterprises in the meat sector, when compared to other agri-food sub-sectors, seem to have a backlog at providing sustainability information. For example, the Global Reporting Initiative (GRI) initiated a study on sustainability reporting in the food processing industry involving 60 enterprises (e.g. Nestlé, Smithfield Foods, Tyson Foods, Unilever) that had issued sustainability reports covering the year 2006. The sector was broken down into the sub-sectors agricultural crops, semi-processed products, meat, fish, dairy and beverages based on the main product enterprises process. The results showed that there has been an overall increase in

sustainability reporting since the first reports were issued in 1991 by enterprises in the agricultural crops and beverage sub-sectors. However, it took ten years for the meat processing sub-sector to start producing reports and even now there is no dramatic growth in the number of enterprises reporting on sustainability in this sub-sector (French, 2008).

It is the objective of this paper to introduce information reference models for European pork supply networks, which (1) give an aggregated overview about information availability and exchange in the pork sector, (2) identify additional information demands of decision makers at different stages of pork production, and (3) identify gaps in the existing information infrastructure. A generic information reference model for European pork production is introduced, representing an ideal-type of model, which can be used as a template for network- or enterprise-specific information models. Further information reference models, indicating additional information demands, as well as gap models, indicating where additional efforts are needed to meet the existing information demands, are presented for the three selected information domains "Food Safety" (representing the social dimension of sustainability), "Quality" (representing the economic dimension of sustainability) and "Global Warming Potential" (representing the environmental dimension of sustainability). All models should provide a base for developing network- or enterprise-specific solutions to meet the existing information demands.

The following chapter (chapter 2) will give an overview about existing information systems in European pork supply networks and will introduce into current challenges for network-wide information management. Chapter 3 will present a generic information reference model for European pork production, representing network-wide information availability and information exchange. Therefore information is assigned to production stages (feed production, pig production, slaughter/processing, retail), product categories (feed, pig, pork) and informational main focus areas (logistics, traceability, food safety, quality, sustainability). In chapter 4 additional information demands as well as existing information, preparation and communication gaps are identified for the three selected application examples food safety, quality and global warming potential. Chapter 5 summarises the paper, concludes the discussion and gives suggestions for future research needs.

2 Information Systems in European Pork Supply Networks

In agri-food supply networks, parts of stage-specific information are relevant for actors on other stages as well, some even for the consumer. As a consequence, intra-enterprise information systems build the base for inter-enterprise information management. However, in the agri-food sector these enterprise-focused information systems are complemented by network- and sector-focused information systems (Schiefer, 2006) targeting at logistics, traceability, food safety, quality and other aspects regarding the sustainability of agri-food production (e.g. global warming impact, organic production, animal welfare). Among these different systems, information exchange occurs, which can be subdivided into (Lehmann et al., 2010):

a) Information exchange among intra-enterprise information systems (vertical and horizontal network dimension),
b) Information exchange among intra-enterprise information systems and network/sector-focused information systems, and
c) Information exchange among network/sector-focused information systems.

Network/sector-focused information systems might be public or private systems, storing and/or processing information, which might be relevant for actors in the sector, and can be a source of information which is also available in intra-enterprise information systems (redundant information), but might also generate new information with added value out of its information base. Examples are the HIT system in Germany (public traceability information system) and the information systems of QS in Germany or IKB in The Netherlands (both quality information systems of respective quality assurance systems).

Information stored in intra-enterprise and network/sector-focused information systems might be used by multiple actors at different stages of production for decision support. However, in the reality of agri-food supply networks provision of information and, related to that, decision making is aggravated through the fact that information sources are both widely spread and not specifically set-up for supporting a decision making process. Figure 1 illustrates intra-enterprise and network/sector-focused information systems in an agri-food supply network as well as an exemplary information exchange among these systems.

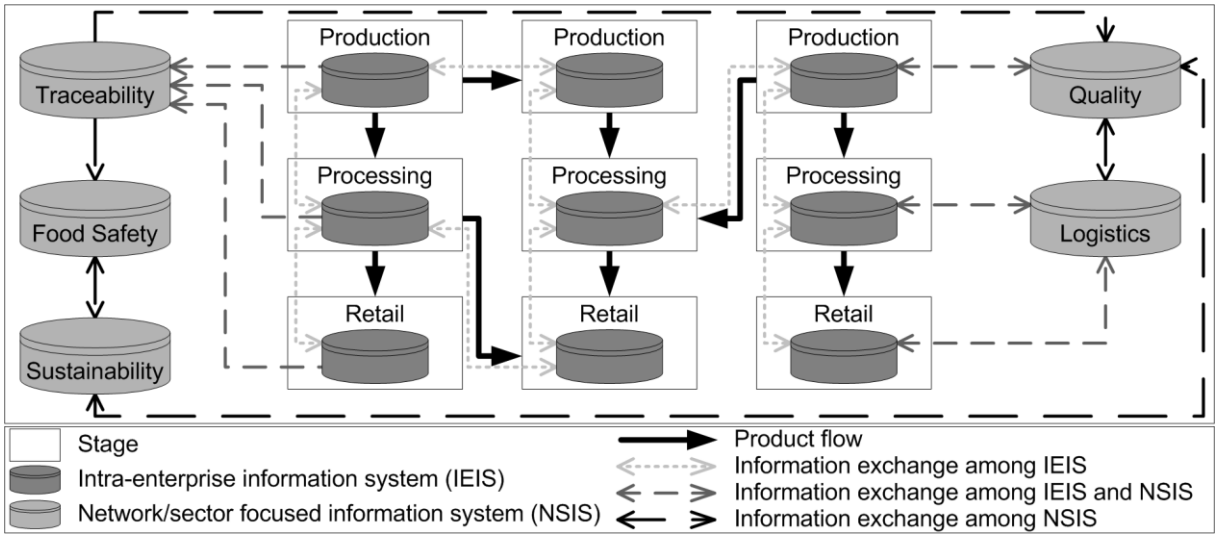

Figure 1. Principle information systems in agri-food supply networks and their exemplary information exchange

As stated in the introduction, the main research objective of this paper is to provide information reference models for European pork supply networks. For that purpose expert interviews were conducted at different stages (in total 69) of eight pork supply networks in five European countries (Germany, Greece, Hungary, Spain, The Netherlands). Detailed information availability and exchange in the investigated European pork supply networks are published by Lehmann et al. (2009). All interviews are part of an inventory of pork supply networks organised within the integrated EU project Q-Porkchains (for the complete inventory results see Trienekens et al., 2009). Figure 2 shows a model of intra-enterprise and network/sector-focused information systems in European pork production. All information systems involved in the expert interviews build the base for the information reference models and are therefore highlighted. Every information system is assigned to feed production, pig production, bundling, slaughter/processing, retail or additional parties.

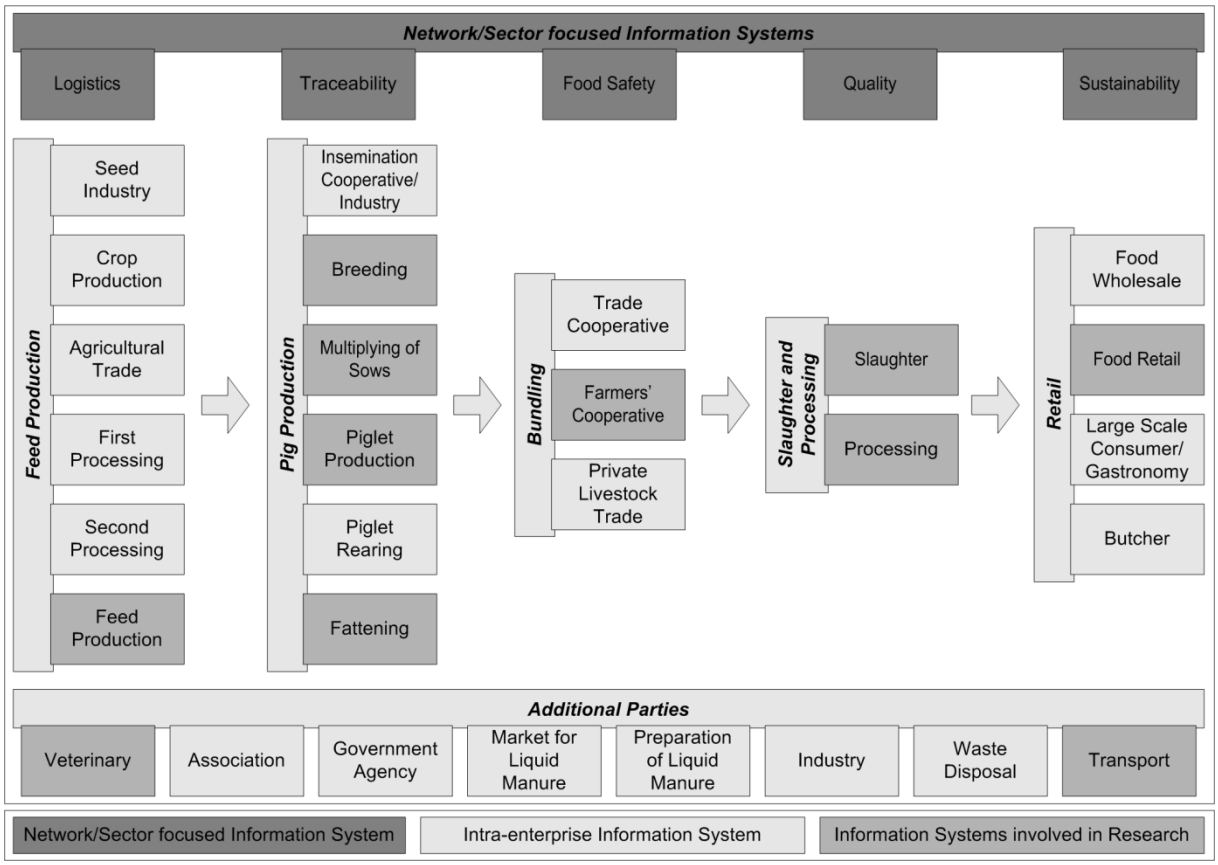

Figure 2. Information systems in European pork supply networks

The following chapter will introduce a generic information reference model for European pork production, which is based upon the aforementioned previous research by Lehmann et al. (2009). The model provides an aggregated view on state of the art of information management in European pork supply networks, therewith supporting involved parties such as enterprises, system developers and consultants in developing enterprise or network specific solutions.

3 Generic Information Reference Model for the European Pork Sector

Information reference models represent an ideal-type of model and provide generic, sector-specific information models, which can be used as a template for network- or enterprise-specific information models (based on Loos and Scheer, 1995; for further information on the reference model perception see Thomas, 2006). They improve the speed and the efficiency of future modelling activities due to information reuse, enhance a shared understanding by providing a common language (Verdouw et al., 2010) and accelerate implementation activities in industry (Hofstede, 2003).

The supply network models published in Lehmann et al. (2009) needed to be simplified for the information reference models. All involved actors are assigned to the following four main production stages (the brackets indicate the assigned actors):

- Feed production (feed production);
- Pig production (breeding, multiplying of sows, piglet production, fattening, farmers' cooperative, veterinary, transport),
- Slaughter and processing (slaughter, processing);
- Retail (food retail).

As a second simplification, available and exchanged information are assigned to the three product categories feed, pig and pork. Moreover, information management as well as related information systems in the agri-food sector follow a historical development of informational main focus areas. Evolving from early logistics requirements, over traceability, food safety and food quality requirements, to recent requirements related to the sustainability of agri-food production, such as the environmental impact or social conditions of production, these five main focus areas have been identified to cover all information presently available and exchanged in European pork supply networks. Hence, information has also been assigned to these five informational main focus areas. However, it is important to consider that these informational main focus areas are not mutually exclusive and are partly overlapping. Logistics and traceability represent a prerequisite for information exchange related to food safety, quality and other aspects regarding the sustainability of pork production. Figure 3 introduces the resulting generic information reference model for European pork supply networks.

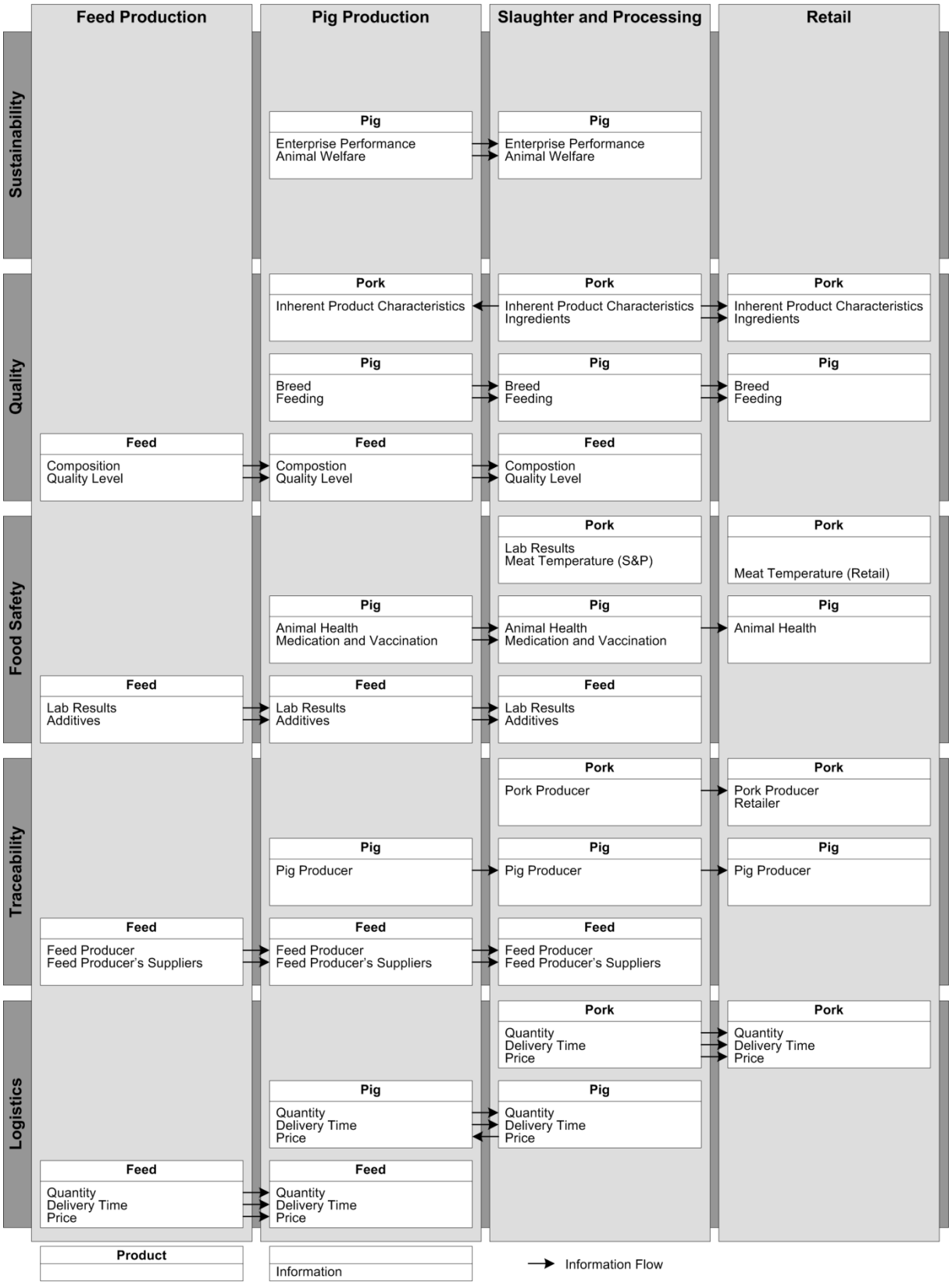

Figure 3. Generic information reference model for European pork supply networks

Further information reference models, introducing additional information demands, as well as different gap models, indicating where additional efforts are needed to meet the existing information demands, are introduced in the following chapter.

4 Demands and Gaps in the existing Information Infrastructure

Enterprises in agri-food supply networks need to find a balance between improvements in their monetary cost-benefit balance to assure general competitiveness in their markets and the society's consideration of the cost-benefit balance related to social, economic and environmental issues. It is essential to understand the relevance and the dynamic developments in those critical success factors and indicators, which determine performance from the view point of enterprises, supply networks and society (Gunasekaran et al., 2001; Schiefer, 2003; Gerbens-Leenes et al., 2003; Gunasekaran et al., 2004). Figure 4 introduces eight priority information domains, which were identified to have demand for additional information provision. Domains and indicators are a result of twelve expert interviews, which have been conducted in addition to the interviews for analysing the information infrastructure of European pork supply networks (chapter 2 and 3). The selected experts are practitioners coming from different stages of pork supply networks and researchers working in the field of pork production. Identified information domains are systematised and structured under the umbrella of sustainability, incorporating the previously introduced five main focus areas of information management.

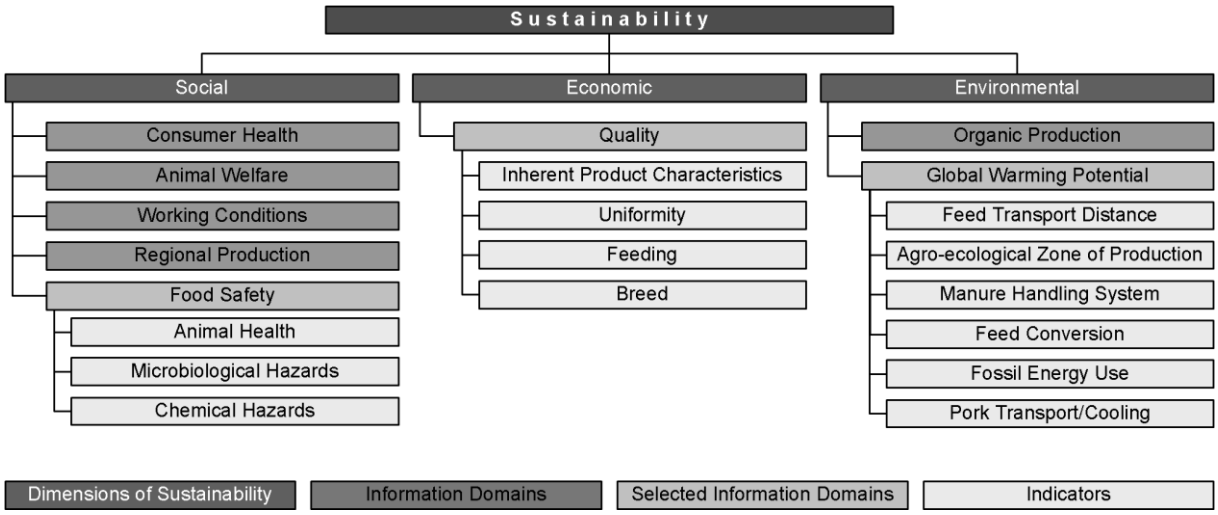

Figure 4. Priority information domains in European pork supply networks

Three information domains have been selected for a detailed analysis of information demands and related gaps:

- Food safety (representing the social dimension of sustainability);
- Quality (representing the economical dimension of sustainability);
- Global warming potential (representing the environmental dimension of sustainability).

The following sections will introduce information demands as well as gaps in the existing information infrastructure. Gaps are identified by contrasting the information demand models with the information reference model and they indicate where additional efforts need to be considered to enable the intended information exchange. Three types of gaps can be distinguished:

- Information gaps (information is not yet available in the information infrastructure);
- Preparation gaps (available information is not sufficiently complying with actual demands);

- Communication gaps (information is available in the information infrastructure but is not communicated).

The following sections will present demands and gaps for the food safety, quality and global warming potential domain.

4.1 Food Safety – Demands and Gaps

All food safety information demands are a result of the aforementioned expert interviews. The food safety indicators as introduced in figure 4 (animal health, microbiological hazards, chemical hazards) are partly further specified. Microbiological hazards are differentiated into pork lab results, meat temperature at slaughter/processing level and meat temperature at retail level. Chemical hazards are differentiated into feed lab results, feed additives and medication/vaccination. The following figure 5 shows a model of identified information demands at the different stages of pork production for the food safety information domain. All information is assigned to feed, pig or pork and the four production stages as previously described.

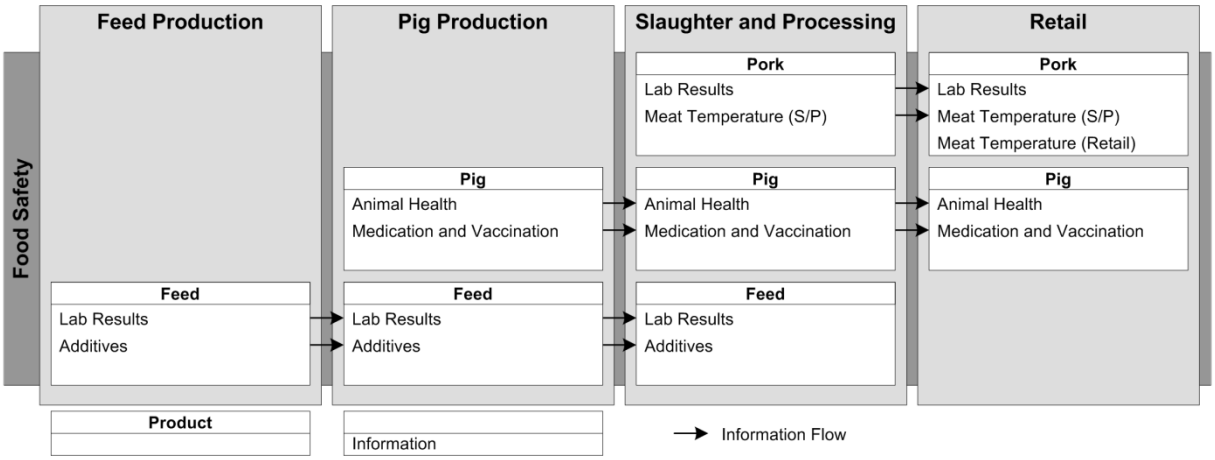

Figure 5. Food safety information demands

Information on lab results and additives of feed is needed at feed production, pig production and slaughter/processing; information on animal health and medication/vaccination of pigs is needed at pig production, slaughter/processing and retail; information on lab results and meat temperature generated at slaughter/processing is needed at slaughter/processing and retail; information on meat temperature generated at retail is only needed at retail.

The gap model introduced in figure 6 is a result of contrasting the generic information reference model presented in chapter 3 with information demands in the food safety information domain.

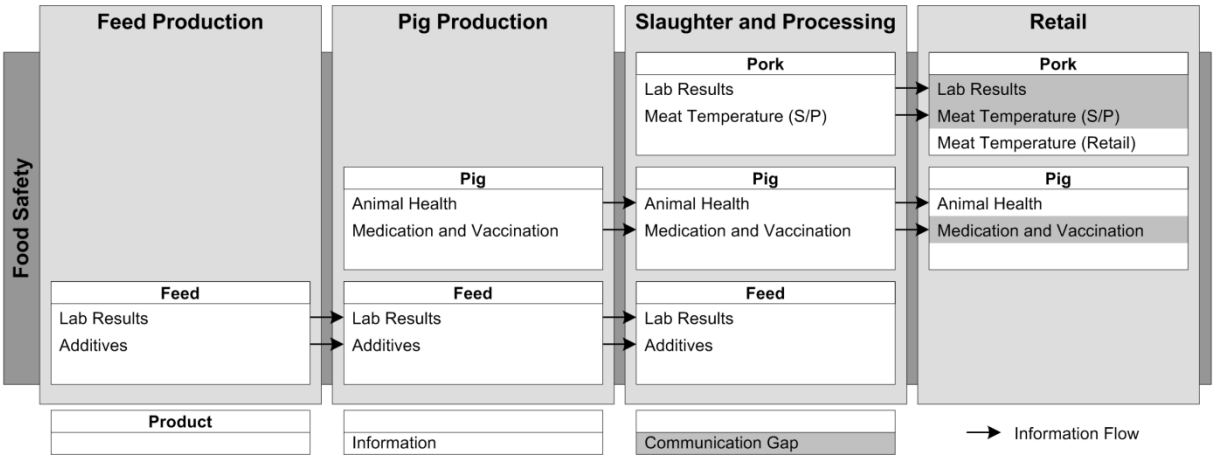

Figure 6. Gaps in the food safety information infrastructure

Information needed for the food safety information domain almost completely matches with the generic information reference model. All needed information is available within the supply network. However, three communication gaps exist at retail level:

- Lab results of delivered pork;
- Meat temperature measured during slaughter and processing;
- Medication and vaccination of pigs.

These communication gaps need to be considered to enable the intended information exchange among slaughter/processing and retail level.

4.2 Quality – Demands and Gaps

All quality information demands are a result of the aforementioned expert interviews. The quality indicators as introduced in figure 4 (inherent product characteristics, uniformity, feeding, breed) are partly further specified. Inherent product characteristics are differentiated into inherent product characteristics (e.g. fat content, water holding capacity) and ingredients of pork and pork products (e.g. salt, spices). Feeding is differentiated into the feeding of the pigs at farm level (e.g. amount of feed, feed conversion) as well as into feed composition and feed quality level at feed production. The following figure 7 shows a model of identified information demands at the different stages of pork production for the quality information domain. All information is assigned to feed, pig or pork and the four production stages as previously described.

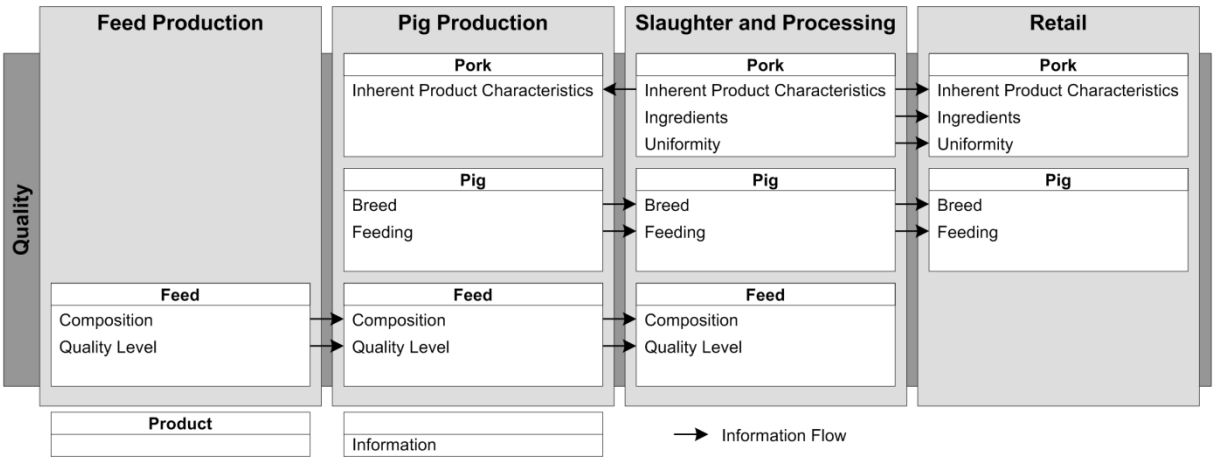

Figure 7. Quality information demands

Information on composition and quality level of feed is needed at feed production, pig production and slaughter/processing; information on breed and feeding of pigs is needed at pig production, slaughter/processing and retail (breed and feeding information are of particular interest for supply networks which intend to guarantee a certain breed and/or feeding, e.g. Iberian dry-cured ham in Spain or Mangalica products in Hungary); information on inherent product characteristics of pork is needed at pig production, slaughter/processing and retail; information on ingredients and uniformity of pork is needed at slaughter/processing and retail.

The gap model introduced in figure 8 is a result of contrasting the generic information reference model presented in chapter 3 with information demands in the quality information domain.

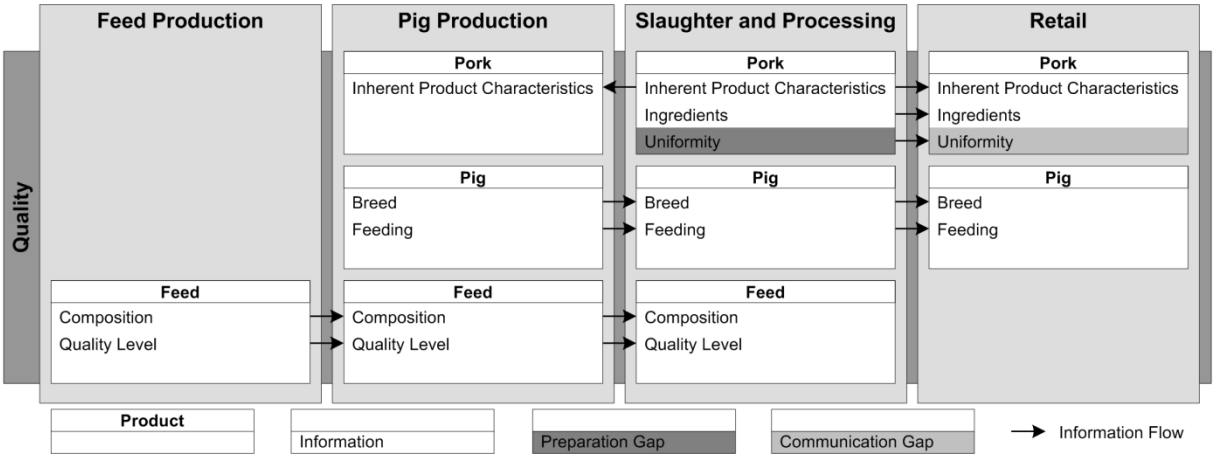

Figure 8. Gaps in the quality information infrastructure

Information needed for the quality information domain almost completely matches with the generic information reference model, except information on uniformity of pork. A preparation gap on uniformity of pork exists at slaughter/processing; hence, provision of uniformity information needs to be improved. This might, e.g., include investments in new equipment. The preparation gap on uniformity is associated with a communication gap at retail level. After preparation, information on uniformity should be forwarded to retail, which might need agreements among slaughter/processing and retail level.

4.3 Global Warming Potential – Demands and Gaps

At all stages of pork production processes are performed that have an impact on global warming. In livestock production emissions of the greenhouse gases nitrous oxide (N_2O) and methane (CH_4) are significant contributors to global warming in addition to carbon dioxide (CO_2) emissions originating from the combustion of fossil fuels. The combined global warming potential (GWP) is commonly measured in CO_2 equivalents where the effect of CH_4 and N_2O relative to CO_2 are 25 and 298:1, respectively. Nguyen et al. (2010) performed a life cycle inventory of greenhouse gas (GHG) emissions from typical pig farming practices in Northwest Europe. This was used in combination with inventory data for slaughtering available from Dalgaard et al. (2007) to identify the main contributors to the GWP of pork supply networks.

Based on the results of Nguyen et al. (2010) and Dalgaard et al. (2007) the following six indicators are identified to be most significant for the environmental impact of different pork production systems:

- Transport distance of feed (transport of feed in tons*kilometres);
- Agro-ecological zone where pigs are raised (representing outdoor climate conditions and manure regulations);
- Manure handling system (individual farm data, e.g. straw based versus slurry);
- Feed conversion (feed use per kg pork produced);
- Fossil energy use during pig production and slaughter/processing;
- Transport/cooling of pork.

The following figure 9 shows a model of the identified information demands at the different stages of pork production for the GWP information domain. All information is assigned to feed, pig or pork and the four production stages as previously described.

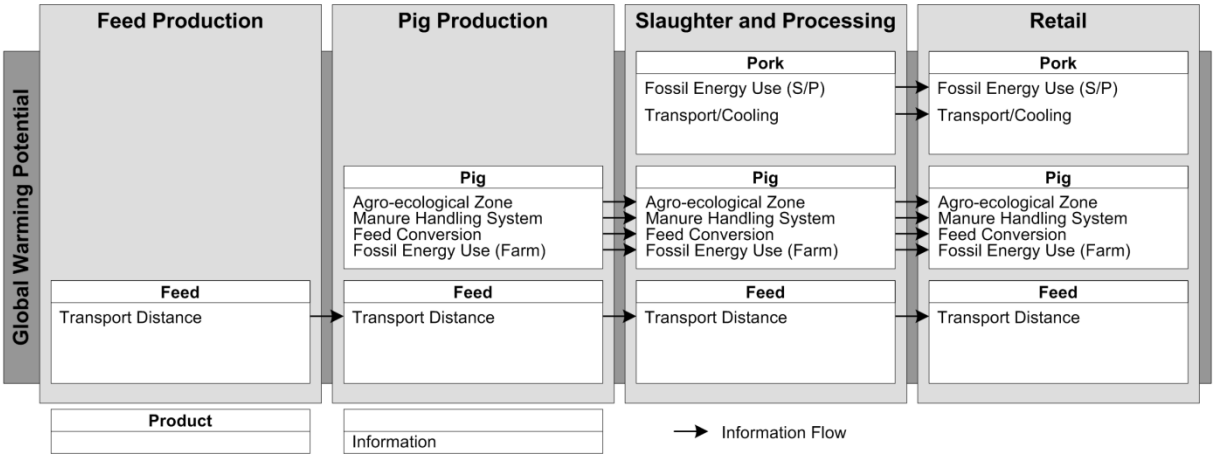

Figure 9. Global warming potential information demands

Information on transport distance of feed is needed at feed production, pig production, slaughter/processing and retail; information on the agro-ecological zone where pigs are raised, manure handling system, feed conversion and fossil energy use on farm level is needed at pig production, slaughter/processing and retail; information on fossil energy use during slaughter/processing and transport/cooling of pork (transport distance and cooling technology during transport) is needed at slaughter/processing and retail.

The gap model introduced in figure 10 is a result of contrasting the generic information reference model presented in chapter 3 with information demands in the GWP information domain.

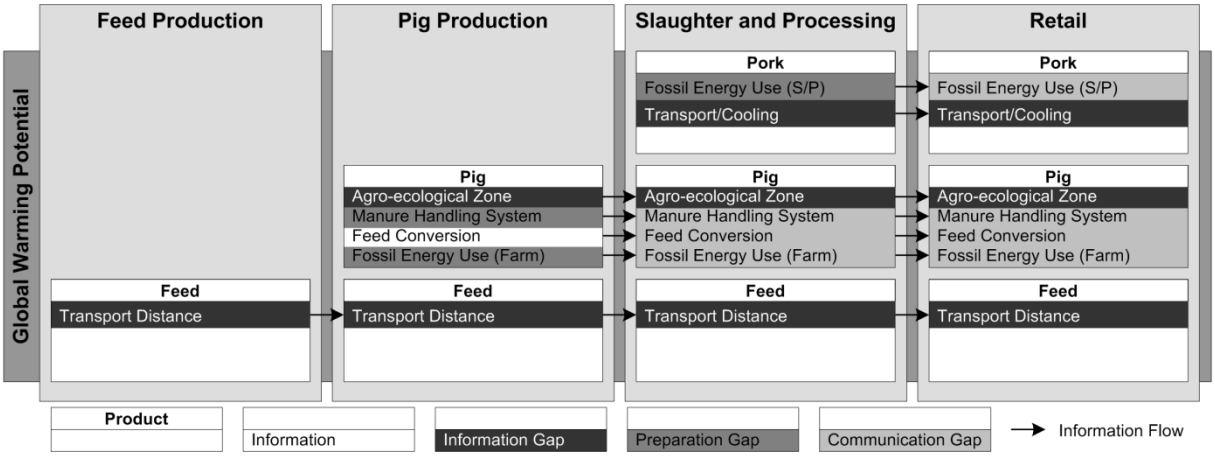

Figure 10. Gaps in the global warming potential information infrastructure

The comparison of the information demands for the GWP information domain and the generic information reference model shows information, preparation and communication gaps at all stages of pork production. Information gaps exist on the feed transport distance at feed production, pig production, slaughter/processing and retail, on the agro-ecological zone at pig production, slaughter/processing and retail, and on transport/cooling at slaughter/processing and retail. Preparation gaps exist on the manure handling system and fossil energy use of involved farms and on fossil energy use of involved slaughter/processing companies. All preparation gaps are associated with communication gaps. After preparation, information on the manure handling system and farm level fossil energy use is needed at slaughter/processing and retail, information on fossil energy use of slaughter/processing is needed at retail. Information on feed conversion is already available in the information infrastructure as part of enterprise performance information at pig production level (see Lehmann et al., 2009); however, communication gaps on feed conversion exist at slaughter/processing and retail level.

5 Summary and Conclusion

The present paper has introduced information reference models for European pork supply networks, which give an aggregated overview about information availability and exchange in the pork sector, identify additional information demands of decision makers at different stages of pork production, and identify information, preparation and communication gaps in the existing information infrastructure. A generic information reference model for European pork production was introduced, representing an ideal-type of model, which can be used as a template for network- or enterprise-specific information models. Further information reference models, indicating additional information demands, as well as gap models, indicating where additional efforts are needed to enable further information exchange, have been presented for the three selected information domains food safety, quality and global warming potential.

In addition to the identified gaps, problems might occur related to a lack of willingness to share information and differing technical standards throughout pork supply networks. As a consequence, governance structures need to be aligned to overcome these deficiencies by inciting enterprises to intensify their collaboration. Due to their important role and their high market penetration in the agri-food sector, quality systems might be an appropriate instrument for implementing such strategies. Further research is needed to identify challenges for policies and to set priorities for improvement actions, which promote the willingness to share information and the integration of enterprises' technical infrastructure, data and applications.

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