Chapter 2
The System of Concurrent Engineering

Nel Wognum and Jacques Trienekens

Abstract Concurrent engineering (CE) has been a major theme in the 80s and 90s of the previous century in research and practice. Its main aim is to reduce time-to-market, improve quality and reduce costs by taking into account downstream requirements and constraints already in the design phase. While starting with a design-manufacturing alignment, gradually the CE way of thinking has been ex-tended to incorporate more lifecycle functions together with a stronger focus on and involvement of both customers and suppliers. Application of CE in practice has led to remarkable cost savings, time reduction and quality improvement. However, many failures have been reported too. Often, the complex system of CE has not been sufficiently well understood, in particular because the system that is needed to market, produce, sell, and maintain the new product, the so-called production system, has not been considered sufficiently. The particular properties of the production system that is needed to really make the new product a success need to be understood well, because they heavily influence the CE process. In this chapter a history of CE is sketched as well as its major achievements and challenges. The essentials of the system of CE are described together with the system that is designed by it: the production system. The production system, as defined in this chapter, is an encompassing system, because it also comprises functions like marketing, sales, production, and maintenance. The interaction between the two systems needs to be taken into account in all CE processes in any application domain. The chapter ends with examples of the food application area. The variety of the system of CE, in terms of different innovation efforts, is illustrated. Some important properties of the result of a CE process, a food production system, are discussed, in particular a food supply chain and its coordination for quality.

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2.1 Introduction

In the ‘80s of the past century, the term concurrent engineering(CE) was coined to indicate a way of working in product development and design to meet consumer demands in shorter time, with fewer errors, and lower costs. CE was meant to improve industry’s competitiveness especially in the West to catch up with the advantage gained by Japanese companies like Toyota.

The essence of CE has been the concurrent execution of design processes with the design of downstream processes, in particular manufacturing. Teams of multiple functions and disciplines were formed to discuss design proposals from different, multidisciplinary, point of views. In these teams, design disciplines, manufacturing and assembly, marketing and purchasing were often represented.

Several new terms were used to indicate more specific approaches of CE, like Design for Manufacturing and Design for Assembly. Since many design and development processes also required the involvement of external technology providers the term Collaborative Engineering has also been used to indicate the concurrent way of working.

Later, more downstream processes became involved in CE, like service and disposal. The necessity to incorporate the customer early in the design process was also recognized in the approach called Open Innovation, in which consumers, customers, suppliers, and OEMs collaborate to identify potentially successful product ideas. In this way waste in terms of time and cost is reduced considerably by the upfront matching of insights of important stakeholders.

All these approaches basically center on boundary-spanning processes. Although the term CE is hardly used anymore, process thinking and boundary-spanning processes have gained more and more attention. Current business requires collaboration between companies, like networks and supply chains, to maintain or improve their market position. Information technology plays a large role in supporting information sharing and aligning people and companies.

Application of CE in practice, in whatever disguise like early supplier involvement and design network, has led to many improvements and time and cost reduction. However, achieving a well-performing CE system is not at all an easy process. It may take years of gradual change and building experience. Moreover, top management needs to have a clear vision. A systems approach is helpful to identify the essential elements that are involved in the CE process as well as their interrelationships. In addition, a clear view on the production system that needs to market, produce, and maintain the new product is necessary.

In this chapter, essential properties of the CE approach are discussed. In Sect. 2.2, the history of CE is briefly discussed together with its achievement as recorded in the literature. In Sect. 2.3, the system of CE is described with its essential elements and relationships. A framework with steps for framing a CE process is presented. A CE system is closely linked to the production system that is the result of or needs to be taken into account in a CE process. The production system is a complex system that needs to be designed or adapted well to make its product (or service) a success. In Sect. 2.4, some examples of the system of CE in the food industry are presented. The framework with steps from Sect. 2.3 is used to frame the relevant innovation processes and indicate the relevant production system that needs to be taken into account. The paper ends with a summary and future challenges.

2.2 History of CE

In this chapter, a brief history is sketched of the main developments in CE in the past decades. First, CE is briefly described, including Early Supplier Involvement. Second, Collaborative Engineering is described, followed by Collaborative Innovation.

2.2.1 Concurrent Engineering

In the 80s, companies were forced to change the product development process from the traditional 'over the wall' approach to more integrated ways of working to beat growing competition, react to reduced product life cycles, and meet changing market and customer demands [1]. They needed to be able to develop new products, which were cheaper, delivered faster and provided a greater functionality [2]. CE was considered to offer a solution to the problems encountered.

CE has had tremendous attention in the literature since Winner et al. [3] in the DoD Institute of Defense Analysis coined the term. The concept has resulted from a USA Defense Advanced Research Projects Agency (DARPA) initiative to improve the product development process. The first definition of CE was [3]:

> Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause the developers from the outset to consider all elements of the product life cycle from conception to disposal, including quality cost, schedule, and user requirements.

This definition stresses the parallel, concurrent, execution of product and process design activities by integrating multiple design disciplines and upstream and downstream functions involved in the lifecycle of a product. Many studies have been devoted since then on further defining this concept. CE is known under various different names, like Simultaneous Engineering, Concurrent Product Development, and Integrated Product Development with definitions slightly different from the one above (see e.g., [4, 5]).

CE has three basic elements: early involvement of participants, the team approach, and the simultaneous work on different phases of product development [6]. CE teams typically consist of the functions marketing, product engineering, process engineering, manufacturing planning, and sourcing activities. The principle focus was the integration of and alignment between design and manufacturing functions, while taking into account consumer demands and supplier capabilities.

Conflicts easily arise within cross-functional CE teams because of different interpretations leading to confusion and lack of understanding. Each team member focuses on different aspects, like marketing on usability, engineering on functionality, production on manufacturability, and purchasing on affordability [7]. In such situations, communication needs to be predominantly personal and involve face-to-face contact.

The early involvement of relevant stakeholders in the design and development process enables exchange of preliminary information. Such information exchange may reduce the number of engineering change orders, which are often the reason for delay in product development projects (see e.g., [8]). Strategies for the exchange of preliminary information exchange may differ with the level of downstream uncertainty and costs of process idleness [9].

To support collaboration in teams and facilitate information exchange and use, many attempts have been made to develop engineering knowledge and collaboration tools (see e.g., [10]). They are, however, still poorly developed [11]. As reported by Lu et al. [11] based on a document from the EU-funded FP6 project VIVACE [12] 26 % of project meetings in Airbus involve international partners, more than 400 one-day trips were taken by Airbus engineers to collaborate with other project members on a daily basis, while they also spent an average of 49 % of their daily activities in meetings and discussions with stakeholders. It can be said that engineering has become a highly collaborative activity in today's industry.

*2.2.2 Collaborative Engineering—CE**

Gradually, the number of stakeholders that needed to be involved in the design process increased. In particular, the marketing and purchasing functions and downstream functions like service and asset recovery have been involved early in the design process. Because products are used and need to be disposed eventually, environmental concerns have also added to product design and development complexity (see e.g., [13]).

The desire for incorporating multiple lifecycle considerations requires tight integration of multi-disciplinary knowledge and collaboration between engineers across various cultural, disciplinary, geographic and temporal boundaries [11]. Todd [14] has defined collaboration as the process of multiple people working together to achieve a greater goal than is possible for any individual to accomplish alone.

Putting the emphasis on collaboration has led to the term Collaborative Engineering (CE*) with the following definition [15]:

> Collaborative Engineering is a systematic approach to control lifecycle cost, product quality, and time to market during product development by concurrently developing products and their related processes with response to customer expectations, where decision making ensures input and evaluation by all lifecycle functions and disciplines, including suppliers, and information technology is applied to support information exchange where necessary.

In addition to involving the purchasing function early in the design process the supplier itself has become a team member. Together with the buyer the parts and materials supply as well as the required logistics are taken into account as early as possible [7]. In addition, the supplier could take responsibility for (parts of) the development process or be involved in different phases, like concept design, engineering, or process engineering (see e.g., [16]).

Early supplier involvement (ESI) as part of CE and CE* has received much attention from researchers and practitioners at the end of the 90s and early 2000s. A literature review by McIvor and Humphreys [16] revealed that despite the potential benefits of ESI negative impact of various factors might exist, like technology uncertainty, low levels of trust between the buyer and supplier, poor communication and co-ordination mechanisms. These factors are similar to those mentioned often also in the context of CE and CE*. Development and monitoring of collaborative relationships are critical for preventing problems with supplier performance [17].

Because fundamental knowledge about human collaboration and its underlying sciences is lacking, a CIRP community has attempted to start a new human-centered engineering discipline by developing a first step of a socio-technical theory of collaborative engineering [11]. This theory builds on various theories from collaboration science, like organizational behavior, social psychology, social choice and decision science. However, many challenges still exist for further developing the socio-technical theory of collaborative engineering.

2.2.3 Collaborative Innovation—CI

Research and Development in large companies used to be internal in the past decades. Many R&D project, however, have led to results that appeared not to be useful for the respective companies leading to waste in terms of time, money and missed market opportunities. However, some of those results, although not valuable for the company itself, turned into valuable spin-off companies [18]. To limit waste and increase the success rate of technology projects, a new business model gradually emerged from Closed Innovation (with extensive control) into Open Innovation.

Open Innovation requires collaboration between a firm and external sources of knowledge, like technology providers, start-ups, small enterprises, consumer organizations, etc. External knowledge increases the potential number of innovations, while also external parties can exploit internal knowledge. Procter & Gamble (P&G), for example, changed the concept of R&D into Connect and Develop (C&D) [19] to indicate the necessity to open up its knowledge and admit external knowledge to keep up and improve its competitiveness. Its experience with CE and CE* models allowed P&G to transit to the new model in reasonable time.

Gradually, the concept is also adopted in more traditional and mature industries like the food industry [20]. As argued by Sarkar and Costa, since the number of actors is large and no one actor alone can meet all, often contradictory, requirements of customers, consumers and legislation bodies, open innovation should be common practice. However, empirical evidence is still anecdotal to date, although the necessity and need for open innovation is gradually recognized.

Vanhaverbeke [21] argues that the open innovation business model should be based on integration of theoretical frameworks, like value chain analysis, transaction-costs theory, rational view of the firm, and the resource-based view (RBV). In addition, governance of innovation networks, on internal, firm and external level, needs to be studied. Networks or supply chains that will eventually produce the product need to be designed also with appropriate governance (see also Sect. 2.4).

2.2.4 CE Success and Failure

CE, CE*, ESI, and CI are approaches requiring collaboration within and across organizational borders. These approaches present complex problems that require a socio-technical approach in which both the technical and social systems and their interaction are taken into account. Koufteros et al. [6] have found that firms that have adopted CE practices report better performance in product innovation and quality, while they are also able to charge premium prices. A firm's internal context is important for facilitating cross-functional integration. Once achieved, external integration is sought for with customers and suppliers to coordinate activities across the value chain. Information technology is an enabler for this way of working. Many success stories can be told with reductions in product development time of 50–70 % (see e.g., [1]), but also many failures.

In the early 90s, a survey of Swedish manufacturing firms showed that Swedish firms had a broad awareness of the importance of product development [1]. Various names have been given to the CE way of working, with integrated product development as the one most widely used. Reducing lead-time was considered the most important goal for CE, followed by customization of products. The dominant element of CE for achieving lead-time reduction is the use of multifunctional project teams, sometimes including customers as well as suppliers, especially in companies successful in reducing lead time (about 50 %). However, such teams are not sufficient for success, because also companies not successful in reducing lead-time (about 23 %) appeared to be using them. Additional methods are needed, like Quality Function Deployment (QFD) and Failure Mode and Effect Analysis (FMEA), which were used by the most successful companies as well and typically in aerospace. In addition, CAD/CAM integration also was more widespread in such companies.

In another study in British industry Ainscough and Yasdani [22] have found that CE was not uniformly spread among British industry sectors. Of the large companies, 100 % claimed to practice CE, with only 63 % of medium-size companies with (101–500 people) and 50 % of the smaller companies. Medium and large companies heavily relied upon formal product development processes, multifunctional teams, tools and techniques, information technologies, and project management activities for executing CE. The functional structure is not suited for executing complex projects like CE projects making various integration mechanisms necessary, although small companies do not seem to need extensive integration mechanisms, because people are closer together.

Implementation of organizational structures needed for executing CE, CE*, ESI, and CI projects, including complex information technologies needed to handle and share the large amounts of information involved in such projects, requires extensive organizational change. As with all major changes, observable also with implementation of ERP systems and other integrated systems, various factors play a role in making such changes a success or failure. McIvor and Humphreys [16] have listed factors that play a role in adopting ESI, which are not much different from the factors mentioned for other major organizational changes.

In the next section the complex system of CE is further explored together with the encompassing production system that is both the result of the CE process and a constraint for it.

2.3 The System of CE

As has become clear in the historical development sketched above, CE has increasingly become a very complex system with many players, locations, information systems, methods and tools that have many different and layered relationships. In addition, as CE is a process of product development and design with the aim to make the product a success, the specific properties of the application domain have to be taken into account. Although the principles of CE are general, they need to be made specific for the different application domains. For example, knowledge of the essential properties of products in specific application domains is needed. These properties influence the production processes that need to be designed together with the design of the product. For example, the short lifecycle of engineering products like cell phones limit the creation of production systems like new companies or supply chains, unless a totally new product family is started. Food products in general have rather long lifecycles, which may justify the creation of new food supply chains. On the other hand the short life of food products, due to perishability, puts heavy constraints on storage facilities, while engineering products may allow unlimited storage during and after production. The production processes, consequently, have different properties to be taken into account during a CE process. In addition, user preferences of products in different application domains may also be rather different. As already indicated above, market knowledge is essential for any CE process to succeed.

While the previous sections have explored developments in CE as well as the essential actors, information systems, methods and tools and their mutual relationships, the production system that needs to be taken into account has only briefly been addressed. Below, the system of CE with its elements and relationships is further explored in connection to its resulting production system. The next section introduced the concept of an organisational system as a basis for the CE system and the production system to be discussed in the subsequent section.

2.3.1 Organisational System

A system, more specifically an organisational system, is inherently a socio-technical system in which technology and organisation need to be aligned with each other to achieve the envisioned organisational goals. In a socio-technical system many different disciplines need to collaborate, while taking into account the social context in which collaboration takes place.

An organisational system can be defined as a purposeful whole in which people perform processes with the help of means, like methods and tools, to satisfy certain needs in the environment of the organisation [23]. These processes are essential for achieving the organisational goals. They transform inputs, like material and/or information, into outputs in the form of products and/or services needed in the environment. There are different types of co-existing processes, like strategic management processes, adaptation or improvement processes, and operational processes, including operational management, primary, and support processes, like the processes of human resource management, maintenance and education. The elements of the system, which are the people, processes, and means, are tightened together by organisational arrangements. These are all formal and informal structural and cultural relationships between the elements. Formal structural relationships reflect the hierarchy, tasks, and procedures as laid down in quality handbooks. Informal structural relationships consist, for example, of the routines that have been adopted by the workforce. Formal cultural relationships are, for example, the norms that underlie the manners and moral of the people in an organization. Informal cultural relationships are manifested in the way people communicate with each other during meetings or coffee breaks.

An architectural view of an organisation with a focus on information flows is depicted in Fig. 2.1 [24]. The figure shows all elements and relationships mentioned above. Most importantly, the figure emphasizes that an organisation consists of activities (making up processes) that are performed by resources (people and means), while organisational arrangements relate activities to resources in the form of procedures, hierarchy, tasks, roles, norms, etc. Activities can be divided into transformation activities and communication activities. Transformation activities transform input information into output information. They also transform input material into output material, but this is not shown in the figure. For example, in a design process product requirements are transformed into a conceptual design; in an

Fig. 2.1 Organisational system with a focus on information

order processing process information of the products status is transformed when the order is processed in a production system. Communication activities transfer information from one activity to another and, as such, between the people that perform the activities. The document flow represents the formal communication in an organisation, while informal communication is more difficult to grasp.

The processes performed in an organisational system determine its behaviour. Processes are expected to proceed as designed, i.e., as laid down in process schemes and handbooks in ISO certified companies. However, this is often not entirely the case, not only because of unexpected disturbances like broken machines or insufficient supplies, but also because of the culture, politics, power, and other aspects involved in collaboration between people [25].

Organisational arrangements as already indicated above represent the structure and culture of an organisation. Part of these arrangements are the normative relationships between elements in the organisation, like organisational hierarchy, reporting relationships, process structure, infrastructure, team structures, procedures and routines, as well as the values, rules and norms that constitute a relatively coherent and consistent set of beliefs and prescriptions that govern the behaviour of people [26]. Normative relationships constrain and channel human behaviour in an organisation. Normative relationships are not static, but are subject to change over time.

Actual behaviour often differs from behaviour intended in the normative part of organisational behaviour. Actual behaviour not only depends on individual human characteristics, but also on relationships and interactions between people who bring their own technical and social knowledge and experiences to the organisation. Commitment, attitude, sentiments, conflicts, autonomous activities are examples of characteristics that influence organisational behaviour. Actual behavior that positively influences organisational performance often is memorized and shaped into normative relationships.

The interaction between normative relationships and actual behaviour is called duality [27]. Actual behaviour may shape the normative relationships, while normative relationships shape behaviour. Actual behaviour is often called social-dynamics.

A system is more than the sum of its elements [28]. The behaviour of a system as a whole cannot be found in any of its elements. A system view, therefore, is a holistic view. It is possible to describe and analyse parts or aspects of a system, but without taking into account their relationships with other parts or aspects, conclusions may not be very reliable. A system view offers an analytic way to focus analysis on a coherent part of the world.

Application of the system view to a real-world problem like CE requires that system borders are determined. Examples of systems to be analysed are the manufacturing process [29], the R&D process [30] or the collaboration process between companies [31]. Determining system borders and the relevant system elements, such as the people that need to be involved, starts with the selection of the focus process, like a design process, a collaboration process, an invention process, a marketing process, a purchasing process, etc., which determines the system borders and the environment of this system. The environment can be the environment within the organisation as well as the external context in which the organisation operates. The context depends on which process has been chosen for in-depth study, the so-called process of focus.

The model depicted in Fig. 2.1 has been used to describe an architecture of a virtual organisation to identify essential capabilities needed for mature performance. A virtual organisation is a temporary organisation, often a complex project, in which several companies collaborate to develop a new product. CE processes are often performed in such a virtual organisation. In Fig. 2.2 an architectural view based on Fig. 2.1 is depicted [24]. In this figure, the essential elements are presented. Each organisation in the figure can be described by Fig. 2.1 separately.

A virtual organisation consists of two or more partners, each of which is part of a mother organisation. A virtual organisation is an organisation with its own goals and strategy for which specific activities and organisational arrangements need to be defined. The processes in a virtual organisation are often restricted to coordination (management) processes, support processes and communication processes, while the primary processes, like design and production processes, are often performed in the mother organisations. Part of the primary processes, like idea and concept development, can also be performed in the virtual organisation.

Essential differences may exist between a virtual organisation and the mother organisations involved. These differences can have a large impact on the performance of the virtual organisation [24]:

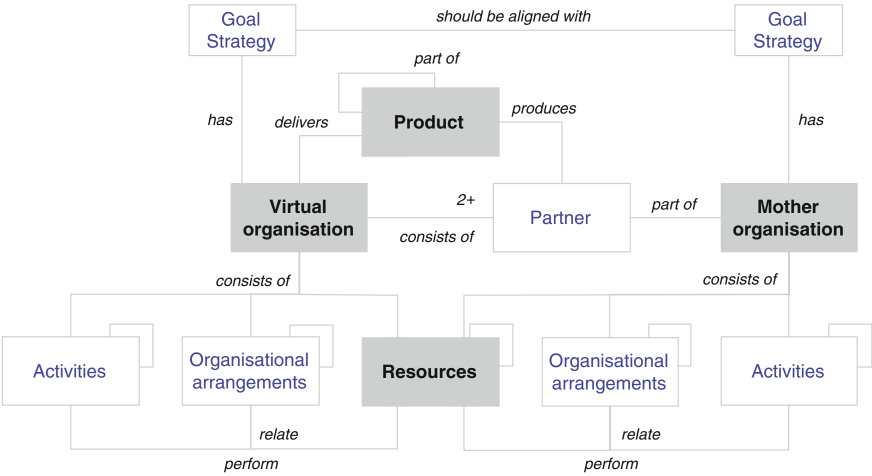

Fig. 2.2 System of a virtual organisation with a focus on information

- The environments (not depicted in Fig. 2.2) of the mother organisations may overlap. For example, in some industries competitors are forced to collaborate (temporarily) in a virtual organisation. Such a situation may hamper collaboration. The transfer of knowledge, e.g., between the people involved may be restricted by national or legal reasons leading to insufficient sharing of the knowledge for performing the processes.
- The resources of a virtual organisation have been assigned by the respective mother organisations to the part(s) that participate(s) in the virtual organisation. Several problems, often reported also in project management literature (see e.g., [32]), may result from this situation. First of all, commitment of the people involved depends on the balance between their normal duties in the mother organisation and their duties in the virtual organisation. Secondly, alignment of competencies, social as well as technical, of people from different companies is essential as well as interoperability of the means (not only technical) involved. Thirdly, the people involved in a virtual organisation have to adapt to the context of the virtual organisation in terms of the social and technical infrastructure defined for the virtual organisation, which is often different from the ones in their mother organisations. However, people will bring working habits, norms and rules from their own company to the virtual organisation. Fourthly, a large part of the activities is still performed in the mother organisation, possibly tipping the scale towards a larger influence of the mother organisation. In summary, large differences between partners, in terms of people, means, organisational arrangements (structure and culture), and goals may negatively influence collaboration in a virtual organisation when not sufficiently recognized.
- The product delivered by the virtual organisation to clients/customers (not in Fig. 2.2) consists of subsystems/parts that are produced in several mother

organisations. This situation poses specific quality demands on product and process information (not in Fig. 2.2) delivered by the partners. For example, difference in terminology and interpretation frameworks (semantics) may disturb communication. In addition, when not sufficiently defined in the virtual organisation beforehand, differences in (documentation) standards and information management facilities may lead to misunderstandings, conflicts and costly delays.

Complex processes, like CE processes and multi-site production processes, as are the focus of this book, are inherently multi-dimensional and multi-level as will be clear from the discussion above. They are multi-dimensional, since they involve different aspects, such as process aspects, people aspects, technological aspects, and organisational aspects. They are multi-level, since they can be specified on the individual level, the group level, the project level, and the organisational level. Moreover, such processes evolve over time, because situations may change and people gradually learn, necessitating changes in goals, activities, and resources. A process approach is necessary to manage collaboration in complex processes, taking into account social dynamics and unexpected events (see Chap. 8).

In the section below the system of CE will be described in general terms together with a process to make this system more specific for a particular application domain. This system description can be used to support analysis of existing CE processes and identify opportunities for improvement. In the subsequent section essential characteristic of the production system, which is the intended output of a CE system, but also constrains this system, will be described.

2.3.2 The System of CE

CE is essentially an innovation system. It is aimed at generating either a totally new product or changes to existing products, which may vary from essential changes to minor variations. As such the CE process influences the production organisation. In the case of new products, a new production organisation may be the result of the CE process, for example a new company with its own supply chain or a new production line in an existing company. During the CE process this new production system is an essential part of the design that is the output of the CE process. In case of adaptions to existing products, the changes that are needed in the existing production system need to be taken into account. These may exist of new tooling, including new tasks and procedures, new materials or parts as input, requiring new suppliers or changes in existing relationships with suppliers. The relationship between the CE system and the production system are depicted in Fig. 2.3.

This view of two co-existing systems may help to frame, study and analyse CE processes in real-life. A step-wise approach, incorporating this view is proposed below. The approach, as all system approaches, is an ‘empty’ framework. For each different situation, a specific description needs to be made with the help of additional theories and knowledge. The steps for framing an existing situation are the following:

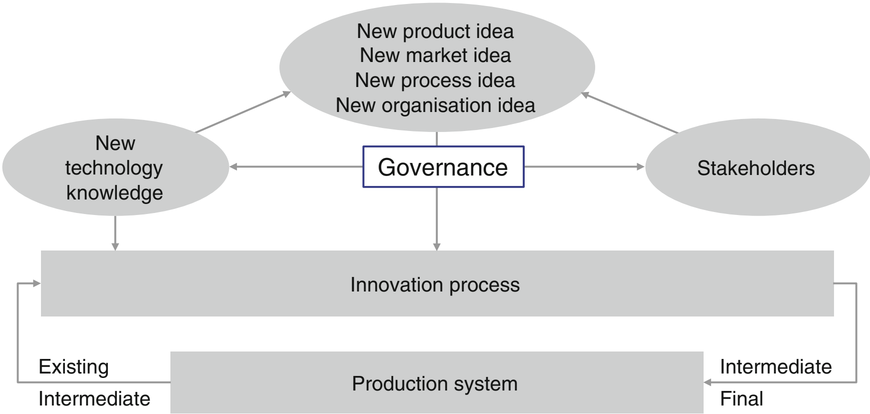

Fig. 2.3 The system of CE

1. Identify the overall goal or vision of the CE system. More and more the goal is encompassing, because not only profitability should be achieved, but also social welfare and reduced impact on the environment. In other words, the CE system should focus on a sustainable output in a sustainable way.
2. Identify the process of focus, i.e., the process that will be the subject of study. A CE process is multi-functional, multi-disciplinary or multi-site, requiring collaboration between different disciplines, functions and roles. For example, the process of focus may be the product development process, the idea generation process, the information management process, etc. The start and end of the process should be determined.
3. Determine the internal and external context of the process. The external context could consist of: departments that influence the process, but are not involved, governmental rules, financial situation, environmental situation, technology providers, etc. If the process is an aspect of a larger whole, like the information management process in product development, the overarching process should be identified. The internal context consists of all departments, organisational levels, or organisations involved including their structural, cultural, and technological properties.
4. Determine the actors, functions or roles that are or should be involved in the process. What does this mean for the departments/organisations that are involved in the process? What humanware is involved in terms of knowledge, expertise and skills?
5. Determine the technologies that are needed/used in the process: hardware and software.

The approach can be used to 'frame' the problem area and identify the specific focus of study. To study this focus process in more detail, additional methods and tools are often needed, for example planning tools. By applying the approach together with these additional methods and tools performance management can be performed, for example, to keep the CE process 'on track' technically and socially.

As an example, consider the *open innovation process*. It is in essence an idea generation and development process with prospective partners. It may be aimed at developing a real business case as output. Below, the steps are applied to 'frame' an open innovation process.

Goal: Develop a new product idea with specific (sustainable) properties for a specific market (including envisioned investments and pay-back time).

Process: Idea generation and development. Source of ideas may be all employees and partners, like suppliers. The steps depend on the output considered. If the output is a business case, then all steps in the funnel process towards a realistic business case are needed.

Context: The business process that needs to execute the business case, finance available or to be made available for the business case, existing regulations, suppliers not involved in the process, customers not involved in the process, etc. There are also requirements for the business case to satisfy: e.g., added value, short- and long-term results expected, etc.

Actors: representatives of relevant departments, suppliers, customers, client/consumer group. *humanware*: knowledge/expertise needed for the specific domains involved; in this case the knowledge may be varied, because the knowledge needed may depend on the ideas generated and developed; people may be involved later in the process when needed; libraries might also be searched.

Technologies: *hardware*: decision support tools, brown paper tools, etc.; *software*: brainstorm techniques, decision support software, financial software for making the business case, project design systems, etc.

A production system resulting from a CE process is often also a complex system (see Fig. 2.4). It consists of several collaborating companies, in networks or in supply chains. The production processes performed by the actors in the system are influenced and restricted by regulations and quality management systems for which suitable governance mechanisms, with appropriate coordination mechanisms [33], need to be installed to make the system working. In addition, the production processes not only depend on the knowledge, skills, and technology that are available in the system in people, hardware and software, but are also available in the environment through technology providers and knowledge institutes.

It depends on the application area which company is most in touch with the end consumer of the production system or is most responsible for the quality of the end product. The way customer demands are gathered and translated into product requirements may vary between application areas. Knowledge of markets and customers is essential for a CE process to develop a sustainable new product and a sustainable production system satisfying existing regulations and quality management systems. Many information and material flows co-exist.

The system presented in Fig. 2.4 is the production system that plays an essential role in any CE process. By focusing on the product only and not on the encompassing system that is needed to needed to market, produce, and maintain the product with appropriate services, the product might fail.

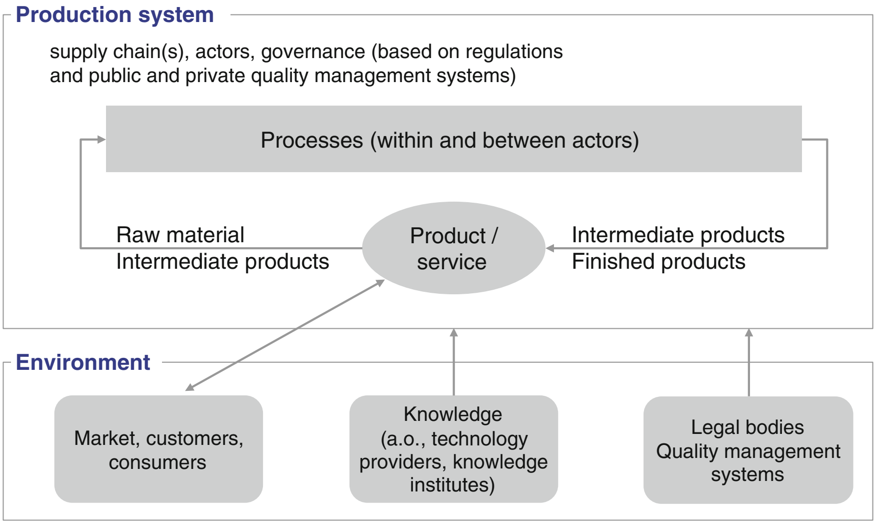

Fig. 2.4 Production system

In Sect. 2.4.2 properties are described of a food production system that is focused on production of quality food, which is often a differentiating characteristic to convince consumers to buy the food.

2.4 Concurrent Engineering in the Food Industry

The food industry, like any other industry, needs to innovate products and processes continuously to remain competitive. Although the food industry has been rather conservative in the past, in the present time the situation has dramatically changed. The food industry has become very complex and dynamic due to increasing product proliferation for serving the ever diversifying and globalising markets [34]. In additions, many incidents have occurred in the recent past, which has damaged consumer trust, requiring actions for producing safe and healthy products. Moreover, many different actors play a role in growing and producing food. Without collaboration between producers, sellers, legislators, etc., a new product is expected to fail. The food industry, like other industries, needs a CE approach for innovation in its products and processes. Before innovation in food is discussed in more detail, properties of the food industry are briefly discussed.

As indicated above, in the last decades several small and large incidents occurred. In the United States, for example, contaminated food causes up to 76 million illnesses, 325,000 hospitalisations, and 5,000 deaths each year [35]. Such and other major incidents that have taken place recently, like the BSE crisis in 1996 and Aviaire influenza in 2003 [36], have raised consumer awareness. More recently, incidents such as the EHEC crisis in 2011 and the mixing of horsemeat with bovine product in 2013 were reported. These incidents damage reputation of food supply chains and reduce consumer trust. Only with much effort consumer confidence can be restored (see e.g., [37]). Consumers increasingly wish to be convinced of the safety and healthiness of food products, which requires food supply chains to be transparent, while traceability of the materials and products needs to be guaranteed. In current global food supply chains this is a big challenge.

Many food supply chains (FSC) act globally. Consequently, worldwide involvement, regulations, requirements, and consequences of actions and decisions need to be taken into account. These differences necessitate additional safeguard for guaranteeing food safety, like specific quality management systems or tracking and tracing systems (see e.g., [38]).

Consumers increasingly require that the intrinsic attributes of the food products they buy are above threshold levels, such as safety, healthiness, colour, and taste. They also more and more focus on extrinsic attributes as well, demanding production processes to incorporate the three sustainable Ps [38]: *People*, availability of a good workplace for people and minding the welfare of animals on farms; *Planet*, environmental care by reducing pollution and the negative impact of pesticides and antibiotics; *Profit*, economic viability and profitability. Not only consumers demand increased sustainability, but institutions and organisations, like governments, environmental organisations, financial institutions, academic institutes, and supply chain actors more and more (are forced to) focus on sustainability.

Many different markets can be distinguished [39]. Each type of market poses specific requirements. Food supply chains need to differentiate themselves to satisfy these different demands. This means also, that structure and organisation of food supply chains need to be different. A supply chain for a stable, high-volume, product will be different from a low-volume, highly specialised, product (see e.g., [40]). Most stable, high-volume, products can be produced in supply chains with a market-type of governance structure (see also Sect. 2.4.2), provided that the minimum level of quality is guaranteed by means of quality management systems that apply to all or most actors in the supply chain [33]. The market influences the type of product that will be developed and, consequently, the organisation of the production system, the specific food supply chain that will produce, sell, or take back the product.

Food supply chains have specific properties that pose many constraints on managing the flow and quality of products. For example, products of food supply chains are perishable and may show considerable differences due to biologic variety even when genotypes and production processes are standardised. Food supply chains may consist of many, often small, actors, making collaboration and alignment more difficult. In addition, margins in the food sector are small, especially in conventional food supply chains with mass products, requiring supply chain actors to improve efficiency of their processes.

Food supply chains are also subject to rules, regulations, and quality management systems that exist to ensure food safety. Rules, regulations, and quality management systems can be found on European Union (EU), world, and national public level, but also on private level, issued, owned or monitored by associations, cooperatives, or individual companies. This situation is comparable to other high-risk areas, like medical products and aviation. Although basic quality has been guaranteed, at least in the EU, additional measures are often needed. For example, several supermarket supply chains demand specific quality from their suppliers with systems like GlobalGap (www.globalGAP.org). Especially for global food supply chains compliance with rules, regulations and quality management systems that exist in the different continents and countries involved is highly demanding.

Another complicating factor is that consumers demand product availability in broad assortments year-round at competitive prices. Changes in the area of trade laws (WTO) have led to more open markets. As a result, a large increase in cross-border flows of livestock and food products can be observed.

As already indicated above, to satisfy the different market and consumer demands, safeguarding or improving reputation and image without increasing costs too much, while remaining sustainable, FSCs need to continuously innovate their products, processes, and organisation. This will hardly be possible without collaboration between relevant stakeholders and taking into account specific properties of the food supply chain.

In Sect. 2.4.1 the CE system in the food industry with its different aspects and elements is discussed. Some examples of innovation activities are presented in terms of the framework presented in Sect. 2.3. In Sect. 2.4.2 essential properties are discussed of the food production system that is the result of or needs to be taken into account in a CE system in the food industry. Many food products are developed with a specific quality claim. To market and produce such products and to maintain the required quality level, safeguards are needed in terms of risk management through contracts. Two extremes of such contracts will be briefly discussed.

2.4.1 Innovation Processes in Food

The development of new products in food supply chains requires an open innovation approach (see Sect. 2.2.3). Involving relevant stakeholders is important for reducing the chance of failure of the new (or adapted) product. For example, changing the package of a meat product requires involvement of the package producer, the consumer, as well as the production of the content of the package. In addition, the packaging machine may also be affected requiring the technology provider to be involved.

Innovation processes must address not only the design of a new or adapted product, but also its market, production process and organisation. Referring to Fig. 2.3, an innovation process often starts with a new idea, which is often a product idea, but can also be an idea for a new market, a new process or new supply chain organisation. The idea may have originated from the creation of new technology or knowledge or may have been formulated by stakeholders like actors of an existing supply chain or consumers, but may also have been enforced by stakeholders like regulative bodies.

The innovation process needs to be well organised. This organisation is often different from the production system resulting from the innovation process. As discussed in Chap. 18, an innovation process requires the free exchange of knowledge to stimulate creativity. However, knowledge may be a critical asset for some companies involved, hampering the free exchange of knowledge. Suitable governance structures are needed to coordinate innovation processes and protect knowledge misuse and leakage when unwanted (see e.g., [41]).

The food production system will eventually produce the product envisioned in the innovation process. The production system, whether already existing or new, needs to be taken into account in a CE process and will gradually be redesigned or realised. Referring to Fig. 2.4, an innovation requires a reorientation on the markets, customers and consumers that will be served. For example, when a product is intended for a regional market only, the supply chain will be rather small and needs to be well aligned to guarantee the quality required. When the product will be made from several ingredients and raw material, the number of supplies can be large and may involve many different supply chains around the world. A new type of fruit or vegetable will need a customer for using or selling the product, while its supply needs to be guaranteed. Trading restrictions and quality demands may heavily impact a steady supply. When an existing product is adapted, the supply and production processes may need to be adapted too to satisfy new demands.

Innovation in food requires thorough understanding of the customers involved. Many new products fail [42], because consumers are not fully understood beforehand. Quality perceptions may change over time. Consumers must be able to perceive that products have a number of desirable properties. Before they are willing to buy new products, they must be able to infer these properties from appropriate cues. These cues are pieces of information, which the consumer uses to make an inference about quality. For example, colour and fat content of meat are an indicator of taste and tenderness. Packages may contain information on intrinsic and extrinsic properties of food products. Brands may give information on quality levels, origin, and production standards.

Innovation in the food area concerns many different product categories. First of all, food products are mostly fresh products, but other products can be preserved for a longer life, like canned or dried products. They can be unprocessed, like fruit and vegetables, but also processed, like sausages or pizzas, according to recipes and the addition of herbs, spices, and other ingredients. Suppliers of fresh products, the growers and farmers, may be involved in the development of new products, like new species resulting from biotechnology of genetics. Processing companies may be involved in new product development requiring the development of new recipes with possibly new ingredients and processing technologies. Often, panels for testing and tasting the new product are installed.

Like in other areas, tools and techniques can be used in the innovation process, such as brainstorming techniques and group decision tools. However, the use of technologies like QFD is limited in the food area. The complexity of food products, the many interactions between ingredients, and the influence of processes on functional properties of the product make it hard to fully apply the technology [43, 44]. The first matrix, however, the House of Quality, is useful to get insight into information necessary to make trade-off decisions and improve the product [43]. In addition, the matrices indicate links between quality characteristics as demanded by the consumer and actors in the production chain [43]. QFD needs to be adjusted to be applicable in the food industry, for example by allowing intervals for target values. In addition, most food ingredients are often physiologically active materials and, hence, still subject to change [43].

The development of new products often requires that new technologies need to be developed. These technologies may be needed on farms for monitoring and controlling growth and health. They may also be needed in processing firms like slaughterhouses, food processing firms, or distributors. Below, two examples are presented of the role technology can play in a food supply chain. The innovation processes are discussed that are needed to develop new technology and use it in a supply chain. The innovation processes are framed with the help of the framework discussed in Sect. 2.3.

Example 1: On the farm, technologies like RFID may affect effectiveness and efficiency. For example, sows producing piglets on a pig farm are nowadays often housed in groups. To manage feeding and monitoring pregnancy, RFID chips are used in ear labels together with automated feeding machines that regulate feed intake by sows, depending on the status of pregnancy. When giving birth is near, a sow is led into a separate area through a special gate of the feeding machine. Also, new growing techniques for fruits and vegetables will influence farming. For example, RFID sensors in vineyards will support farmers in regulating water supply (see e.g., [45]).

The first innovation process that can be distinguished is the development of suitable RFID chips. This innovation process needs to be specified:

1. The goal of development should be clear. Will the chip be used for process control in a pig stable or will it be used for climate control in a field outdoors? What impact will it endure from its environment? Will the chip be disposed of after use or will it be reused? Is additional effort needed to reduce its impact on the environment? What are constraints on size and weight? What are maximum costs for the chips to allow any profit? In defining the goal and constraints, not only the technology provider, but also representatives of farmers, need to be involved.
2. The process of focus in the example is the development of the chip by the technology provider. Trade-offs need to be made between a general chip and a dedicated chip. A chip applicable in more than one application domain, e.g., not only in pig farming, but also in monitoring cow performance, will be more expensive at first, but might have a larger gain in the longer term for the provider. Development of a generic chip requires the technology provider to

involve representatives of different application areas. In addition, material suppliers may play a large role as well.

3. In the example of an RFID chip for sow management, rules and regulations exist for limiting the number of physical interventions in an animal. This means, that the chip should be capable of replacing existing identification labels. In addition, the use of artificial material for the casing of the chips is not only impacted by regulation, especially environmental rules, but also by the environmental condition in which the chips will be used. The innovation process needs to take into account these regulations as well as the constraints put by the application area. In addition, the financial situation plays a role. What can the company invest itself? What amount must be borrowed? The innovation process of the example will consist of all stages, from idea development to prototype, when the provider does not produce a chip already. Otherwise, the innovation process will consist of adapting an existing product to make it suitable for one or more specific application areas.
4. The actors in the example will be the technology provider, representatives of farmers, and material providers in first instance. Knowledge is needed of material involved, RFID technology and its potential, and of farming conditions in the application areas.
5. The technology provider needs tools to design a chip and produce and test a prototype. It also needs tools and techniques for communicating with the other actors. Business cases may be used to investigate the feasibility of a particular design or pilot projects in an application area.

The output of the innovation process consists of the chip design, the service surrounding it (e.g., a data service for housing data read from the chips, or a recovery process for reusing obsolete chips) and the production system that markets, produces and maintains or takes back the particular chips.

The second innovation process that can be distinguished in example 1 is the process innovation that is needed in the application area that adopts the RFID chip. In the example of sow management, the farmer needs tools for applying the chips in the ear of the sow. He/she needs a handheld reader for reading the information on the chip: identification of the sow. The identification is connected to an information system with information, e.g., on the age of the sow, number of deliveries, insemination date, pregnancy duration, and necessary feed intake. The adoption of the RFID chip will dramatically change the sow management process. Group housing is possible for pregnant sows as well as dynamic feeding regimes. The innovation process can be specified with the 5-step approach:

1. The goal of the innovation process needs to be specified. In the example it could be increase of animal welfare, cost reduction in feed administration, time reduction in managing sows, increased efficiency in the whole process.
2. The process of focus is the change process from the old situation to the new situation. In this process the technology provider plays a large role including one or more information system providers, the farmer, and possibly the feed

provider. Accreditation bodies are also involved, because the resulting process must comply with existing regulation and quality management systems.

3. Sow management is subject to regulation and quality management systems, which specify the minimum housing conditions for individual and group housing. Sow management is the process of tracking progress of insemination and pregnancy, housing sows ready to deliver, housing and feeding sows with piglets, moving sows when piglets have been weaned, managing these sows to get them ready for new insemination. The process is an aspect of pig farming both for breeding of particular pig species and for production of pig meat. Pig farming for meat production consists of growing piglets and fattening pigs until they are ready for slaughter. The quality of piglets may increase by better sow management. The innovation stops when the change has been accomplished.
4. The actors involved in the change process are the farmer, the technology provider, an information system provider, and possibly the feed producer and stable builder. The farmer takes the lead, because it is his process that needs to be adapted.
5. Preparation of stables is needed, requiring the building of new housing or rebuilding existing ones according to the guidelines of regulation and quality management system. Pilot projects may be used to test the new process in a small group of sows. The information system may be gradually built or may be an existing system is installed and tuned to the situation. Additional modules may gradually be added.

The result of the innovation process is a changed production system, the production of piglets.

The two discussed innovation processes co-exist and interact, but they need to be viewed analytically as separate innovation processes, because, although actors may overlap, they play different roles in both innovation processes.

Example 2: In the processing stage of food production new technologies will affect the production process. An interesting example is the level of automation that can be achieved in the slaughtering of pigs. Horsens slaughterhouse of Danish Crown in Denmark has achieved an impressive level of automation in the first stage of the slaughter process where pigs are killed with CO_2, cleaned, and opened, intestines are removed and carcasses are cut in half before they are stored for 24 h in a cooling area (for a demo, see http://danishcrown.com/Danish-Crown/Welcome-to-the-virtual-slaughterhouse.aspx). The consequence of such an approach is that farmers need to adopt a higher level of standardisation with respect to the genotype of pigs they use, the feeding regime, and farm management. In this way weight and size of pigs as supplied to the slaughterhouse remain within more standard ranges as required for the machines in the slaughter line. Another example is a new cooking device, such as the Nutri-pulse e-Cooker, developed by IXL (www.innovation-xl.com), (see [46]), dramatically influencing the processing of food by increasing sustainability and safety in use. The cooker reduces cooking time at low temperature with minimal effect on proteins, vitamins, antioxidants, sugars, and other (healthy) substances.

As in example 1, the development of the automation technology is the innovation process of the technology provider together with the slaughterhouse. The technology may be an adaptation of existing technology or may have to be specifically developed for the customer at hand, the slaughterhouse. The production system eventually is the process of marketing, producing, selling, installing, and maintaining the automation equipment in the slaughterhouse.

The slaughterhouse itself undertakes a rather encompassing change process by adopting, installing, and using the automation equipment. A suitable implementation strategy has to be chosen to enhance the chance of success. Because margins in pork production are rather small, any disturbance of daily operation may have large consequences. The change must, therefore, be planned and executed carefully. Moreover, since investments are huge, continuity of the business needs to be ensured as much as possible for the longer term. Actors involved are various, from process managers of the slaughterhouse, to technology providers (automation equipment for slaughtering, slaughter-line experts, etc.), farmers, feed companies, legislators, customers, like food processing companies, etc. The result of the innovation process in the slaughterhouse is an efficient slaughter process with limited number of people in the line and reduced floor space.

Another promising area for innovation in the food area is the development of chain-wide information systems. The need for providing consumers with safeguards on the safety of food and enabling the fast recovery of errors in the food supply chain, the exchange of information in the supply chain is essential. Chain-wide information exchange reduces the asymmetry of information between actors in a supply chain. Although there are successful examples of chain-wide information systems, many barriers also still exist. Successful examples are often systems that involve only part of a supply chain, like health management systems on a farm relating farmers, slaughterhouse, veterinarian, and possibly the feed company (see e.g., wikiporc: www.wikiporc.fr).

Chain-wide information systems for traceability are more difficult to realize. In a recent project the feasibility of a chain-wide information system is investigated based on the application of RFID on pig farms and DNA profiling for tracing the origin of a piece of pig meat (see [47]). It appeared that the supply chain studied is not yet ready for adoption of such a system, while some farmers were already convinced of the use of RFID for enhancing effectiveness and efficiency with RFID on their farms. Local optimization by improving farm processes might lead to profit for farmers, but the gain might be larger when the impact on the whole downstream supply chain is also recognized and measures are taken to optimally benefit from the efficiency and quality gain on farms. DNA profiling was seen as profitable, but requires investments in a unique population of boars used for insemination. As already indicated above, margins in the food area are regularly small. Investments in chain-wide changes require, moreover, the involvement of many supply chain actors, which may each have a different interest in participating in the innovation. Costs and benefits may also be different in different stages of the supply chain. Only when these costs and benefits are equally shared, innovations are more likely to happen.

Many new food products are developed for a specific quality label (see e.g., the farmer cooperative BESH, www.besh.de). Supply chains producing products with a specific quality label need to be organized well to maintain the quality of the product as claimed in the label and to prevent image loss. In the next section, examples are given of supply chains that have been organized for production of quality products. The examples are taken from case studies in the domain of pork supply chains in Europe.

2.4.2 A Food Production System—Integration and Coordination

As explained above, the result of an innovation system is a production system. Innovation in food mostly leads to a production system in the form of a food supply chain. It is important for an innovation system to understand the properties and constraints of a food supply chain to develop a production system that is sustainable in terms of profit (the product must keep value for the consumer), people (food must be safe as well as the process conditions for people and animals), and planet (impact on the environment must be as small as possible). Food supply chains are subject to many demands and constraints like any other high-risk area like the medical area and aerospace. In this section, integration and coordination mechanisms of food supply chains are discussed that are needed for achieving and maintaining the quality level required for keeping consumer interest in buying and enjoying the food products. Examples are give of different supply chain structures.

Worldwide, food products have to comply with legislation and quality demands. In developing new products and the processes for producing them, legal and quality rules play a large role. Many products are developed with a specific quality claim. For example, three EU quality systems exist to promote and protect food products (http://ec.europa.eu/agriculture/quality/schemes/index_en.htm). These are protected designation of origin (PDO—covers agricultural products and foodstuffs which are produced, processed and prepared in a given geographical area using recognised know-how), Protected Geographical Indication (PGI—covers agricultural products and foodstuffs closely linked to the geographical area. At least one of the stages of production, processing or preparation takes place in the area), and Traditional Specialty Guaranteed (TSG—highlights traditional character, either in the composition or means of production).

Legislation and quality demands, specifically the public ones on European as well as national level, set a minimum level of quality that should be achieved as a reaction to the already mentioned food crises. For example, the European Union has issued the General Food Law (GFL), which emphasises that firms hold primary responsibility for quality in the chain. Many chains go beyond this basic level to distinguish themselves to the end consumer by setting additional, often private, quality demands. Maintaining the additional quality level needs additional efforts to avoid reputation disasters. The question that can be raised is what integration and coordination mechanisms are needed in different chains with different quality and market characteristics. Integration and coordination between supply chain actors is needed to cross boundaries between the different functions, processes, and material and information flows in a supply chain [48].

Integration can be expressed in terms of inter-company relationship structures. A supply chain with a minimum level of integration shows mainly market relationships, while a high level of integration exist in vertically integrated supply chains with tightly controlled relationships. In between these two extremes various hybrid forms exist as depicted in Fig. 2.5. At the left side of the continuum companies in a supply chain are relatively independent, while at the right side there is strict control over the flow of goods and information. From left to right various forms of integration can be found from informal (long-term) relationships to formal written contracts and long-term collaboration agreements.

To achieve integration coordination mechanisms are needed to manage the flow of information and materials and to take decisions. Examples of coordination mechanisms are standardisation of output, process, or knowledge and skills. More expensive and complex coordination mechanisms to achieve integration in a supply chain are coordination by hierarchy or plan and coordination by the creation of lateral linkages [49, 50]. With respect to relationship structures as depicted in Fig. 2.5, coordination tends to be more complex and expensive going from left to right.

The quality level that supply chain actors together want to achieve may influence the degree of supply chain integration required. Quality management systems in general provide the standards and monitoring mechanisms for achieving, maintaining, or improving the desired quality level and to communicate quality across the supply chain and to end consumers. Quality standards need to comply with, but often extend EU, national, and sector rules and legislation. We may distinguish public from private quality management systems based on ownership of the quality standards. In addition, quality management systems may apply to a whole supply chain or to single supplier-client, or company-to-company, relationships. Monitoring of compliance to the standard is performed by either the owner of the standard or by an external auditing agent. Ownership determines the decision authority and flow of necessary information. Information is also needed to assess compliance to the standard. Finally, only a few actors in the sector or a large part of supply chain actors may adopt a quality management system.

Below, we describe some examples of pork supply chains in the EU based on case-study research performed in the EU (EU-FP6-036245-2) project Q-Porkchains. The examples show different integration and coordination mechanisms related to the quality management system(s) adopted by the respective supply chains. More examples can be found elsewhere [51].

Fig. 2.5 Range of supply chain relationships

Example 1: Private chain-wide quality management system as industry standard.

Supply chains with this type of system have a private chain-wide quality management system on top of the baseline quality standards set and monitored by the EU, the state, or other public actors. Most actors in the whole industry sector have adopted the private chain-wide quality management system. In this sense, the system can be considered as the industry standard. In addition to the chain-wide quality management system, chain actors my set private standards for the immediate linkages in the chain on top of the chain-wide quality management system. These additional link-to-link standards have also been widely adopted in general by the respective horizontal stages of the supply chain. This type of supply chains can be found in the fresh pork meat industry in Germany, where QS (Qualität und Sicherheit) is the chain-wide quality management system, the fresh pork meat chain in The Netherlands, where Integrated chain control (IKB) is the chain-wide quality management system, and in the fresh pork meat chain in France, where VPF (Viande de Porc Français) is the chain-wide quality management system.

In the Dutch fresh pork meat chain contracts are relatively rare, although different relationship structures can be found at different stages of the supply chain. Contractual relationships mainly exist in the breeding stage, while free trade is found in farmer-slaughterhouse relationships. Most relationships can be characterised, though, as informal and long-term. The Dutch government sets baseline standards for the sector in accordance with EU legislation, but even exceeds EU legislation, for example with respect to animal welfare. Additional standards have been set by the private society of pig companies 'De Groene Belangenbehartiger' and by the Product Board of Cattle and Meat (PVV). In both groups all supply chain stages are represented. The standard is called IKB (Integraal KetenBeheer—Integrated Chain Control). IKB is widely used in the Dutch pork industry: more than 90 % of the pigs produced in The Netherlands are IKB pigs. IKB is a chain-wide quality management system. It sets requirements for each linkage in the chain. Chain actors may put additional demands on top of IKB requirements.

Compliance with the IKB standard is outsourced to a third party certifying agency, like Lloyds and SGS. In addition, large chain actors, like retailers, undertake their own inspection of their direct suppliers. IKB is only communicated in inter-chain linkages. Retailers use their house labels to communicate quality to end consumers. With respect to coordination, IKB acts as standardisation of processes and outputs. Since the supply chain is very large with many actors and supply relationships, it is unfeasible for one actor to coordinate the whole supply chain.

New products in this type of meat supply chain need to be suitable for a mass market. New products can be fresh, like a new meat cut, or meat sold in a package with ingredients that can be used for cooking. Products can also be processed. Examples of processed products are hamburgers, shoarma, or sausages.

Example 2: Public chain-wide quality management system.

Supply chains with this type of system have adopted a (voluntary) public chain-wide quality management system on top of the baseline quality standards set and monitored by the EU, the state, or other public actors. These public chain-wide quality management systems are mostly regional systems, like Protected Designation of Origin (PDO) and Protected Geographical Indicator (PGI). Such systems tie production to a specific region. Within these regions, the quality management systems may be widely used. The Spanish Iberian PDO supply chain is an example of a supply chain in this category.

All chain actors have signed contracts with the control board PDO Guijuelo, which coordinates the supply chain. Between chain actors, market relationships exist with long-term relationships. The control board Guijuelo is an independent regulatory council responsible for setting the PDO standard and monitoring compliance with this standard. PDO standards are protected by EU legislation. This protection is assigned only when certain strict conditions are met. Most importantly, the product characteristics must be (partially) determined by or linked to the specific geographical location [52]. The PDO must satisfy in addition European and Spanish regulation for meat production. The PDO Guijuelo quality standard is owned by the regional government, which also monitors compliance with the standard next to independent monitoring agencies. The PDO label is communicated in intra-chain relationships as well as to the end consumer.

With respect to coordination, the control board PDO Guijuelo uses coordination by hierarchy and plan. Standardisation of processes and outputs is provided by the PDO standard, making market relationships possible.

The PDO standard applies to the Iberian ham sold worldwide. Innovation in this type of product is limited, because of the recognised taste and quality of the product. However, new products may be developed based on Iberian pork, fresh as well as processed. The Iberian pig contains more than only ham. Other parts of the pig are sold as fresh meat to restaurants and special butchers.

The examples that have been briefly described above show that different quality management systems exist with different chain governance structures and coordination mechanisms. In developing supply chains with suitable structures not only the bi-lateral relationships between actors need to be taken into account, but also the upstream and downstream relationships to prevent suboptimal arrangements [53].

2.5 Summary and Further Research

At the time CE emerged, the importance of cross-functional thinking was gradually recognized. Since then, in particular medium and large companies have adopted CE practices [54, 55]. Although many terms have been used for cross-functional and cross-border collaboration, the essence has been the formation of teams in which also the customer and supplier are involved [56, 57]. Information technology plays a key role in facilitating information sharing between the many actors involved [58].

Although the term CE has gradually disappeared, it has set the scene for further development of collaborative product development in networks and supply chains of essential stakeholders [59]. By adopting CE the necessary skills/competencies have become in place for gradually moving towards CE*, ESI, and CI to manage the complexity of continuously innovating products and processes [57].

New theories or frameworks need to be developed to identify patterns within or between industry sectors and product development project types. Several attempts have been made in the past, while new challenges have also emerged. In this chapter CE has been described as an innovation system aimed at generating a production system that is capable to sustainably produce the new product envisioned. The production system is often also a complex system of collaborating companies, for example in a supply chain. Based on this view a framework has been proposed that can be used to describe CE processes and its resulting production system for further analysis. Examples of innovation in the food industry have been presented, which show that several innovation systems may co-exist and interact. In addition, specific properties of food production systems, in particular integration and coordination, have been presented that need to be taken into account when developing a production system.

Since the framework for framing the system of CE and the accompanying production system presented in this chapter is rather abstract and generic, it needs to be made specific for different application areas. For example, planning and scheduling techniques may help to more specifically identify the order of activities and their timing. Performance management methods may help to determine useful indicators for managing performance of the CE process. In Chap. 8 of this book, an example of a more specific framework is presented.

Specific attention is needed for the properties of the resulting production system. The examples from the food area have shown that specific requirements exist for food production systems. These may be different for production systems in other application areas, given the nature of supply chains and necessary arrangements, like contracts, referring to the necessary degree of integration and coordination, in these areas. Theories of coordination, social-dynamics, organisation structures, etc., may help to further develop the description of the production system.

References

1. Trygg L (1993) Concurrent Engineering practices in selected Swedish companies: a movement or an activity of the few? J Prod Inn Manag 10(5):403–415
2. Clark KB, Fujimoto T (1991) Product development performance: strategy, organization, and management in the world auto industry. Harvard Business School Press, Boston
3. Winner RJ, Pennell JP, Bertrand HE, Slusarczuk MM (1988) The role of concurrent engineering in weapons system acquisition. IDA R-338. Institute for Defense Analyses, USA
4. Bergstrom RP (1990) Assembly, promises and simultaneous engineering. Prod 102(2):50–56
5. Cleetus J (1992) Definition of concurrent engineering. CERC Technical Report CERC-TR-RN-92-003, Concurrent Engineering Research Center, West Virginia University, USA
6. Koufteros X, Vonderembse M, Doll W (2000) Concurrent engineering and its consequences. J Op Manag 19:97–115
7. O'Neal Ch (1993) Concurrent engineering with early supplier involvement: A cross-functional challenge. Int. J Purch Mat Manag 29(1): 2–9

8. Eden C, Williams T, Ackermann F, Howick S (2000) The role of feedback dynamics in disruption and delay on the nature of disruption and delay (D&D) in major projects. J Op Res Soc 51:291–300
9. Terwiesch C, Loch CH, de Meyer A (2002) Exchanging preliminary information in concurrent engineering: alternative coordination strategies. Org Sci 13(4):402–419
10. Chen Y-M, Liang M-W (2010) Design and implementation of a collaborative engineering information system for allied concurrent engineering. Int J Comp Int Manuf 13(1):11–30
11. Lu SC-Y, Elmaraghy W, Schuh G, Wilhelm R (2007) A scientific foundation of collaborative engineering. Ann CIRP 56(2):605–633. doi:10.1016/j.cirp.2007.10.010
12. VIVACE (2005) Collaborative methods and tools. VIVACE Forum, CERFACS, EADS, Warwick
13. Lenox M, King A, Ehrenfeld J (2000) An assessment of design-for-environment practices in leading US electronic firms. Interfaces 30(3):83–94
14. Todd S (1992) Collective action: theory and application. University of Michigan Press, USA
15. Willaert SSA, de Graaf R, Minderhoud S (1998) Collaborative engineering: concurrent engineering in a wider context, A literature review. J Eng Techn Manag 15:87–109
16. McIvor R, Humphreys P (2004) Early supplier involvement in the design process: lessons from the electronics industry. Omega 32:179–199
17. Zsidisin GA, Smith ME (2005) Managing supply risk with early supplier involvement: A case study and research propositions. J SCM Fall 41(4):44–57
18. Chesbrough H (2004) Managing open innovation. R Techn Manag 47(1):23–26 Jan–Feb
19. Dodgson M, Gann D, Salter A (2006) The role of technology in the shift towards open innovation: the case of Procter & Gamble. R&D Manag 36(3):333–346
20. Sarkar S, Costa AIA (2008) Dynamics of open innovation in the food industry. Trends Food Sci Technol 19:574–580
21. Vanhaverbeke W (2006) The inter-organizational context of open innovation. In: Chesbrough H, Vanhaverbeke W, West J (eds) Open innovation: researching a new paradigm. Oxford University Press, UK
22. Ainscough M, Yasdani B (2000) Concurrent engineering with British industry. Concurrent Eng 8(1):2–11
23. Boer H, Krabbendam JJ (1993) Inleiding organisatiekunde (Introduction to organisational science). University of Twente, Enschede, The Netherlands
24. Wognum PM, Faber ECC (2002) Infrastructures for collaboration in virtual organisations. Int J Netw Virt Org 1(1):1–23
25. Schein H (1996) Culture: the missing concept in organisation studies. Adm Sci Quart 41 (2):229–240
26. Scott WR (1995) Institutions and organisations. Sage, Thousand Oaks, p 178
27. Giddens A (1984) The constitution of society: an outline of the theory of structuration. University of California Press, Berkeley and Los Angeles
28. Flood RL, Jackson MC (1991) Creative problem solving: total systems intervention. Wiley, Chichester, p 250
29. Boer H (1990) Organising for manufacturing innovation: the case of flexible manufacturing systems. PhD Thesis, University of Twente, Enschede, The Netherlands
30. Weerd-Nederhof PC de (1998) New product development systems, operational effectiveness and strategic flexibility. PhD Thesis, University of Twente, Enschede, The Netherlands
31. Faber ECC (2001) Managing collaborative new product development. PhD Thesis, University of Twente, Enschede, The Netherlands
32. Kerzner HR (2013) Project management: a systems approach to planning, scheduling, and controlling. Wiley, USA
33. Wever M, Wognum PM, Trienekens JH, Omta SWF (2010) Alignment between chain quality management and chain governance in EU pork supply chains: a transaction-cost-economics perspective. Meat Sci 84:228–237
34. Trienekens JH, Wognum PM, Beulens AJM, van der Vorst JGAJ (2012) Transparency in complex dynamic food supply chains. Adv Eng Inf 26(1):55–65

35. Smith-DeWaal C (2003) Safe food from a consumer perspective. Food Control 14:75–79
36. Plaggenhoef W van (2007) Integration and self regulation of quality management in Dutch agri-food supply chains. PhD Thesis, Wageningen University, Wageningen, The Netherlands
37. Greenberg J, Elliot Ch (2009) A cold cut crisis: listeriosis, maple leaf foods, and the policy of apology. Can J Comm 34:189–204
38. Wognum PM, Bremmers H, Trienekens JH, van der Vorst JGAJ, Bloemhof JM (2011) Systems for sustainability and transparency of food supply chains—current status and challenges. Adv Eng Inf 25(1):65–76
39. Grunert KG, Wognum N, Trienekens J, Wever M, Veflen Olson N, Scholderer J (2011) Consumer demand and quality assurance: segmentation basis and implications for chain governance in the pork sector. J Chain Netw Sci 11(2):889–897
40. Franks J (2000) Supply chain innovation. Work Study 49(4):152–155
41. Gambade PJP (2014) Management of innovation in networks and alliances. PhD thesis, Wageningen University, Wageningen, The Netherlands
42. Grunert KG, Valli C (2001) Designer-made meat and dairy products: consumer-led product development. Livest Prod Sci 72:83–98
43. Benner M, Linnemann AR, Jongen WMF, Folstar P (2003) Quality function deployment (QFD)—can it be used to develop food products? Food Qual Pref 14:327–339
44. Costa AIA, Dekker M, Jongen WMF (2001) Quality function deployment in the food industry: a review. Trends Food Sci Technol 11:306–314
45. Matese A, Di Gennaro SF, Zaldei A, Genesio L, Vaccari FP (2009) A wireless sensor network for precision viticulture: the NAV system. Comput Electron Agric 69:51–58
46. Foodvalley NL (2013) 50 selected food innovations. Foodvalley NL, Wageningen
47. Wognum PM, van Erp T (2013) TIVO—Traceability of individual pigs in the organic chain. Report GO-EFRO project TIVO. Wageningen University, Wageningen, The Netherlands
48. Romano P (2003) Coordination and integration mechanisms to manage logistics processes across supply networks. J Purch Suppl Manag 9(3):119–134
49. Mintzberg H (1979) The structuring of organization—a synthesis of the research. Prentice-Hall Inc, Englewood Cliffs
50. Thompson JD (1967) Technology and structure. Organizations in action. McGrw-Hill, New York, pp 51–65
51. Trienekens J, Petersen B, Wognum N, Brinkmann D (eds) (2007) European pork chains. Diversity and quality challenges in consumer-oriented production and distribution. Wageningen Academic Publishers, Wageningen
52. Raynaud E, Sauvee L, Valceschini E (2005) Alignment between quality enforcement devices and governance structures in the agro-food vertical chains. J Manag Gov 9:47–77
53. Wever M, Wognum PM, Trienekens JH, Omta SWF (2013) Supply chain-wide consequences of transaction risks and their contractual solution: towards an extended transaction cost economics framework. J Supply Chain Netw 48(1):73–91
54. Stevenson M (2013) The role of services in flexible supply chains: an exploratory study. Int J Agile Sys Manag 6(4):307–323
55. McLay A (2014) Re-reengineering the dream: agility as competitive adaptability. Int J Agile Sys Manag 7(2):101–115
56. Alguezaui S, Filieri R (2014) A knowledge-based view of the extending enterprise for enhancing a collaborative innovation advantage. Int J Agile Sys Manag 7(2):116–131
57. Chang D, Chen CH (2014) Understanding the influence of customers on product innovation, Int J Agile Sys Manag 7(3–4):348–364
58. Blessing Mavengere N (2013) Information technology role in supply chain's strategic agility. Int J Agile Sys Manag 6(1):7–24
59. Peruzzini M, Germani M (2014) Design for sustainability of product-service systems, Int J Agile Sys Manag 7(3–4):206–219