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Coordination routines at different modular levels for the diffusion of explicit and tacit information: the case of the engineering department of a globally-distributed corporation

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Abstract

This paper examines the need to identify an appropriate coordination mechanism in the case study of Leden Electronics (a fictitious name of an existing multinational corporation). With branches in the USA, Europe and Asia, it is grappling with the salient dilemma concerning the need for including remote employees and other stakeholders to support corporate innovation practice, whilst preventing the loss of knowledge due to employee turnover or 'silent theft' in the near future. We find that the present business model does not wholly afford Leden Electronics alignment around its dual dependency on knowledge-based and globally-distributed production. We study these issues by means of concepts of integrative knowledge and modularity in order to provide reasons that help explain the present usage of the corporation's embodied knowledge. Such insight sheds light on opportunities that have been 'latent', that decision makers may lever to shift the corporation's coordination modes that are likely to yield better direct performance while keeping longer term goals, such as innovation on the one hand and preservation about globally-distributed complex projects on the other hand, in sight.

1. Introduction

In the era of globalization, companies face a two-pronged challenge. Firstly, to keep up with the myriad of multiple and changing customer demands and identify those customer requirements that an organization must respond to so as to stay in business. The higher the customer requirements, the more organizations need to specialize their activity set and are subsequently forced to apply implicit (or tacit) coordination knowledge to deal with their growing challenges (Loasby 1998; Schilling & Steensma 2001). Much of such knowledge is qualitative and typically embedded within the corporate culture. Hence, it is typically hard for new ‘hires’ to ‘bundle’ such tacit knowledge. Instead it takes an ‘experienced translator’, one who has been around and about the company. Or a ‘trusted type’ who is known to individuals, and has practiced within groups, and can access higher-order, un-codified routines (Kogut & Zander, 1992), which reside within communities of practice (Brown & Duguid, 1991). Contrary to explicit knowledge, tacit knowledge cannot be shared with by direction by means of documents but it needs interaction (Nonaka, 1991; Grant, 1996). Face-to-face contact is a proven mode for such communication. A consequence is that organizations ’do’ more than they ‘know’ explicitly (Araujo et al., 2003). Therefore, they have difficulties to diffuse their know-how and to keep it within the organization when staff leaves for a new job or because of retirement.

Secondly, new technologies afford organizations new opportunities. The complexity level of technologies, meaning the level of embedded operational knowledge at a specific product quality level (Sturgeon, 2002), makes tasks more understandable, which increases their analyzability (Perrow, 1970). Complex technologies afford individuals within organizations to function independently. Therefore, they offer organizations the opportunity for subsequent modularization. Examples are the diagnostic tools of automobile service organizations, which indicate the broken components within a car, or the digital control of washing machine service organizations, which verify the state of the products from a remote point of view such as the service spot.

Developments in customer demands, on the one hand, and technological opportunities on the other form a spiral. In order to be effective, each organization needs to position itself between developing client demands and technological opportunities. Each organization can position itself by means of variety of organizational arrangements (centralization-decentralization; make-or buy; autonomous vs. conscious cooperation; market vs. hierarchy; component change vs. architectural change and so on) to effectively tie these developments together. This process of positioning takes places in a specific institutional context (formed by law, labor market, culture, infrastructure) and can be realized by making the choice for an appropriate business model, because it addresses specific organizational needs (Johnson et al, 2008). The different pace of changes in customer demands and technology may even lead to a systemic change (Langlois, 2003).

We approach this issue by focusing on the concepts of coordination routines and supporting technologies by means of a modular design of competences. In such a system, each subsystem is a functional entity, meaning that it performs a specific competence, capability or skills (depending on the level of analysis). These units are related by coordination entities on the same level of analysis and range from standardized via routines towards improvisation. On the one hand, the attention in a major part of the literature on modularity aims to achieve (nearly) decomposable systems with loose (standardized) relations between the related subsystems. On the other hand, there is much discussion about the role of integrative (improvisatory) mechanisms in the capabilities literature, especially where tacit knowledge is a key to performing functional capabilities. The present paper posits the following central issue:

How and why weak and tight integration compare, particularly, are they mutually exclusive, is there an interplay or are there different options?

In order to aid comprehension, we refer the metaphor of the Solera process applied for the production of sherry). In the Solera process, several barrels (modular buildings blocs) are filled with sherry of the same vintage year (coordination at a specific modular level), and subsequently tapped and filled with younger wine (coordination at a deeper modular level) and so forth. The wine in the barrels in the bottom layer has the highest age (highest modular level) where the sherry has finally developed its special taste, based on a producer’s vision (core ideology determines the structure of coordination). New wine (new knowledge by means of improvisation) may add interesting new flavors during the process but the blend stays rooted in the producer’s past (innovation because of new customer demands or new ideas employees is path dependent).

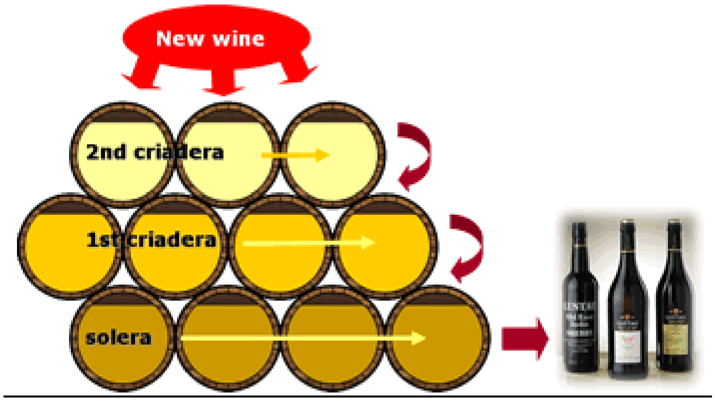

Figure 1 The Solera process

We study these issues by researching the array of coordination competences in the case study of the Engineering department of CCC, one of the business units of Leden Electronics (a fictitious name of an existing multinational corporation). Leden is a major supplier of industries ranging from automotive, appliance, aerospace and defense to telecommunications, computers and consumer electronics, with units in the USA, Europe and Asia. They struggle with the challenge to participate in innovation processes and renew their knowledge sets including remote colleagues and other stakeholders, whilst preventing the loss of knowledge due to employee turnover or 'silent theft'.

The paper is structured as follows. The theoretical part will define the platform that consists of the relevant themes on the issues of integrating competences (implicit and explicit knowledge, modularity and options for coordination). We will apply this platform for the diagnosis of Leden's problems of coordinating competences.

2. Theory

2.1 Knowledge for integration

The various evolutions that confront companies are not temporally aligned. Besides, they are mingled with institutional changes (law, labor market, culture), or social technologies as Nelson and Sampat (2001) refer to them. In certain periods, customer demands are relatively hard to respond to due to low state-of- the-art technologies while at other times new technologies offer radical answers to previous difficult-to-overcome demands.

Historical studies have shown a variety of organizational answers to meet this dual evolution, especially by their product and process innovations in cooperation with other stakeholders (Chesborough, 2006). Langlois (2003) has indicated that the Chandlerian revolution of the late 1800s (typified by a higher presence of conscious coordination) was needed to align the then available technological opportunities to utilize their capacity, whereas at the end of the 20^{th} century companies were able to use the market to align their knowledge supported by flexible technologies, ICTs and institutional arrangements. Both transformations directions were intended to seize the opportunities of specialization, whereas the network structure offered more flexibility and a larger set of participating contenders.

Such innovations are the result of technical and administrative changes in organizations (Damanpour, 1996). Technical innovations are directly related to the basic activity of an organization such as the technology used, whereas administrative innovations refer to the structure of manufacturing processes by means of coordination efforts. Henderson & Clark (1990) refer to the latter as architectural change by means of information-filters and problem-solving strategies between groups. These architectural changes may be detrimental for incumbents and require explicit managerial attention. Leonard-Barton (1992) suggest that in a product and process development process attention should be spent to managerial systems but foremost to core values and norms for the development and coordination of competences, especially where the need for non-codified knowledge is concerned.

In line with Nelson and Winter (1982), we apply the concept of 'routines' to describe the knowledge behind organizational activities. This concept has been introduced in *Organizations*, where March and Simon (1958) focus on decision- making activities to solve particular problems, for the smooth functioning of primary processes. Generally, routines are typified as a recognizable pattern of action, repetitive, collective, and existing of independent actions enabled and constrained by artefacts such as written rules, forms, and work logs (Pentland & Feldman 2005)[1]. Routines are difficult to change because they concern functional activities (sales, logistics, service operations management, and marketing), have a highly tacit content and are linked to decision-making and coordination in the face of goal-setting and performance achievement (Teece et al., 1997). That does not mean that they are inflexible, because recombination of their contents and mutations cause modifications (Cohen 2007; Becker et al., 2006).

[1] We follow the performative approach that describes the actual behavior and not the prescription of activities.

Nelson and Winter (1982) did not specifically distinguish between functional and coordination routines although manufacturing and the M-form were respectively seen as routines for production and coordination (Winter, 1990). But do we need coordination routines anyway since the repetitive pattern knits together the underlying activities and so arranges a coordinated system? This question involves the generation of that repetitive pattern, which cannot be realized without supporting, indirect efforts (Loasby, 1998), especially in the face of systemic change (Langlois, 2002). We therefore follow Chandler, who emphasized that "even more important are those (coordination) routines to coordinate these several functional activities." (Chandler, 1992, p. 86).

We conclude with two examples of such routines. First, Hansen (2002) provides an integrative routine of a large multidivisional multinational in electronics, namely short paths of direct relations between engineers of various divisions (as opposed to indirect relations). These short inter-unit knowledge paths may have been supportive for transferring non-codified knowledge, but tend to be harmful for transferring codified knowledge. Second, Gibson & Gibbs (2006) study virtual teams within multinationals, in which people of different units collaborate. They conclude that, although these relations between different units are needed to exchange knowledge over the company, they do not perform as effective as real team because they lack mutual knowledge, which has a negative outcome on innovation. These two examples illustrate the difficulty of realizing effective integration within and between routines; therefore the need arises for additional coordinative efforts.

2.2 Modularity

In line with Grant (1996), we apply a modular approach to understand the related coordination routines. Modular systems have been described as (nearly) decomposable subsystems related by architecture, interfaces and standards for the coordination between functional subsystems or modules (Clark & Baldwin, 1997; Langlois, 2002). It is stated that modularity is the result of technological advances (maturity offering standardization) and differentiation of client demands. Modularity allows for the application of more specialization and so productivity (Schilling & Steensma, 2001). Besides, it enables autonomous innovation because of trial-and –error processes at component level (Langlois & Robertson, 1992).

The emphasis in the literature is that modular production networks are linked by means of embedded coordination, meaning coordination of processes by means of standardized and codified component interfaces without constant managerial efforts (Sanchez & Mahoney, 1996; Sturgeon, 2002). Several authors do also pay attention to the need of more intensive integrative efforts, for two reasons. First, these efforts are required if the use of codified knowledge is not sufficient because of high complexities and variance (Brusoni, 2005). That explains the presence of systems integrators according to Hobday et al. (2005). They refer to the Chandlerian role (capacity utilization) between Smithonian firms (specialization). Indeed, Miles et al. (1997) claim that knowledge sharing combines explicit and implicit information over the different modules (or cells, as they call them). Collaborative skills are necessary, ranging from output demands, operating protocols towards direct cooperation (collaborating by doing).

Second, in times a major changes (client demands, technological innovations), managerial efforts are needed to reconfigure the architecture of the system (Henderson & Clark, 1990; Langlois, 2002). The classic example is the development of the assembly line by Ford to enable the throughput of model T (Hounshell, 1984). Brusoni (2005) states that desintegration at firm-level must be reintegrated at project level. Strongly coupled linkages are needed and require a solid understanding of the business opportunities and recursive process between different competencies. This sets limits to modularization so that a system is not fully decomposable. Nickerson and Zenger (2004) come up with a three level description of a system:

1. Organization: non decomposable subsystems: interactions among distinct knowledge sets are extensive. The elements of subsystem display dense relations in a mutual order.

2. Modularity: nearly decomposable: the information needs between subsystems require relations on a tight-loose range (Langlois & Robertson, 1992; Miles & Snow, 1994):

   - Centralized or complex networks with many (de-) codified information needs between different sequentially related subsystems.
   - Decentralized or dynamic networks: loose relations (codified output relations through benchmarks, strategy guidelines) between pooled subsystems.

3. Market: price-mechanisms between decomposable firms based on codified specifications.

We conclude that on a higher level (decentralized networks, markets), flexibility is realized by standardized devices, because subsystems have a lower average complexity and simpler relationships in comparison with their underlying parts. We argue that on a deeper level functional subsystems tend to have more intensive relations, which requires tight coordination of processes. Such subsystems are not decomposable for two reasons. First, the same persons are involved in different competences and, second, the different competences are performed in the same stages. The next section goes into detail on the possible forms of coordination to meet the information demands of the modules.

2.3 Business model coordination by standards, routines and improvisation

We apply the concept of business models to illustrate the changes coordination of companies. The term 'business model' emerged at the dawn of the digital age (Magretta, 2002). Its potential to combine the architecture of professional activities with ICT standard designs has turned the idea of business model into one of the most discussed concepts today. The reasons for their popularity are that business models make sense because they provide options to make work more efficient, flexible and smarter (Malone et al., 2006). Outsourcing, partnerships, alliances are only a few of the often used terms to denote business models. In essence, a business model is the unit of analysis that depicts the sources for the firm's value creation and explains the underlying logic how such value is delivered to customers (Amit & Zott, 2001; Magretta, 2002). The models create a narrative of the business system that the company applies, which is a set of processes by which the company carries out its business. These processes have a goal (strategy), are being performed by the use of people and equipment (technology with certain dependencies creating information needs) and need to be coordinated (structure as information processing device, answering the information needs) (Davenport and Short, 1990). In our study, we focus on the coordination within the business model.

So far, we have not touched on the subject how specific components of the business model might be arranged. This is relevant as the mix of functional and coordination routines must dovetail with the processes of applying, spreading and retaining (explicit and implicit) knowledge to offer customers added-value. We study this coordination issue and seek to provide reasons that help explain the present usage of the corporation's embodied knowledge.

Firm processes stem from knowledge-bases at different levels (competences, capabilities and skills). The functional knowledge elements are the units of analysis for contingency theory (Donaldson 2001). Studies concentrate on their uncertainty and interdependence (Donaldson, 2001), which are "intermediate (work related) variables" (Mintzberg, 1979: 221) between on the one hand contingencies such as the external environment and internal technology, strategy and size, and the other hand the organizational structure. Contingency theory claims that the efficiency of task-performance is dependent on the congruence between contingency and structural (administrative) variables. In our study, we typify functional knowledge by the difficulty (indicating complexity and variability) (Perrow) and the interrelations (Thompson) of their components.

As stated before, the level within the system is a first indicator of the difficulty of the components. The deeper the competences are located, the more tacit knowledge is needed to perform and to coordinate the activities. Different means of coordination are mentioned in the literature, on a scale from standardization via routines until improvisation which allow for an increase in the tightness and tacitness of transferred knowledge.

- Grant (1996): distinguishes between integrating devices between routines (complexity, tacit content) and direction (standards, codified). Flexible technologies and open standards for instance allow for more standardization (Sturgeon, 2002; Langlois, 2003).
- Moorman and Miner (1998): draw a distinction between improvisation/routines (both with tacit content, simultaneous activities) and rational planning. Pentland and Feldman (2005) also assign improvisation as a part of (performative) routines.
- Ciborra (1999a) distinguishes between improvisation and routines. The main point he makes, concerns not (only) the short feedback loop of improvisation, but the nature of improvisation, which is a defining moment for future developments. In line with this distinction, we state that the improvisation breaks away from the existing pattern (explorative).

The application of this range 'standardization- routines-improvisation' to a modular system results in the notion that deeper in the system more improvisation as coordinative means is used, that on medium level coordinating routines are feasible and on the surface standardization is appropriate.

2.4 Developments

Increasing client demands drive the need for extra technological knowledge requirements. In turn, this raises the dynamism and/or complexity of functional routines and the need for elaborate coordination to achieve effective performance. However, when technology is able to absorb relevant knowledge, it offers the potential for making capabilities more functional, subsequently, routines simpler and eventually standardizing routines. As stated before, these developments do not always have the same temporalities (Langlois, 2003). Therefore, in order to bridge the levels of client demands and technological opportunities, coordination swings back and forth between improvisation and standardization (Ciborra, 1999a). These swings may offer new inputs to knowledge (by improvisation), support development and distribution of knowledge (through routines in which members collaborate) and finally contribute to the retention of knowledge (by routines and standardization). Guided by their ideology, each surviving organization creates itself a unique path of innovation by mixing new inputs with historically dependent routines and standardization (Collins & Porras, 1996).

These swings result in trajectories that organizations follow through an imaginary space which is stretched between coordination dimensions such as cooperation (x-axis: conscious cooperation vs. autonomous behavior) and governance (y-axis: hierarchy vs. market) as shown in Figure 2 (Langlois & Robertson, 1995).

The x-axis refers to the need for intensive collaboration, the y-axis to the setting (internal-external) in which cooperation takes place. The dimensions compare with the "level of diffusion of knowledge" (x-axis) and the "level of codification" (y-axis), which results in the need to exchange and willingness to the focus on codified work, respectively (Boisot & Child, 1996).

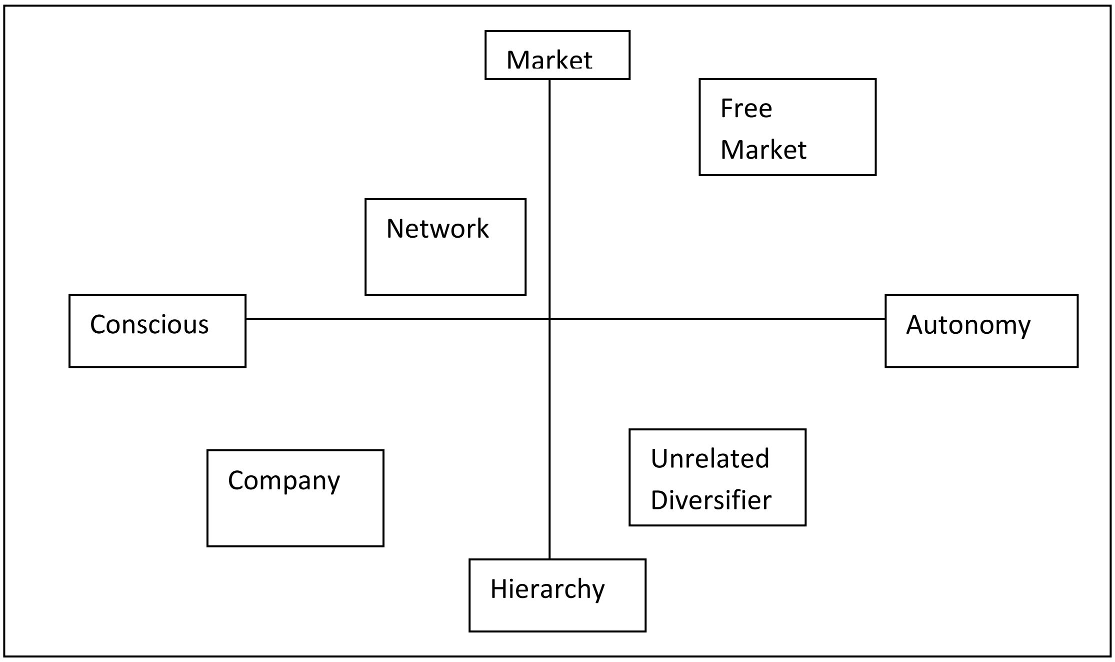

Figure 2: business models by means of coordination dimensions

The combination of dimensions creates a typology that defines codified ‘bureaucracies’, free ‘market systems’, isolated ‘fiefs’ (cultures wherein information is controlled) and flexible ‘clans’ (see Figure 3). The lower level of the figure indicates internal setting that enables the exchange of complex information. The left part of the figure refers to a situation in which extensive integration (is needed to) take place. Companies/fiefs offer the opportunity to extensively exchange complex information. The application of the social Learning Cycle in the I-Space (Boisot, 1999) leads to a change trajectory where the market demand for specialization leads to a network of separate modules that, supported by ICT’s, learn to relate via commonly developed standards (conscious coordination but higher codification). Open systems and standards increasingly become available through further technological developments and institutional arrangements so that more autonomous coordination is possible. The free market comes in sight, until systemic changes are needed under the pressure of client and technological change (back to improvisation).

During their change trajectories, companies face the ambidextrous task to on the one hand, to exploit the opportunities of their present business model while, at the other hand, explore the promises of a new model (O’Reilly & Tushman, 1996). Studies show that organizations need to change their model in order to fit disruptions in the environment. In this view, transformation is the leap of an individual organization to a new form[2]. Incremental changes have the function of 'lining' the business within a certain form[3].

	UNDIFFUSED INFORMATION	DIFFUSED INFORMATION
STRUCTURED INFORMATION	**2. BUREAUCRACIES** • Information diffusion limited and under central control • Relationships impersonal and hierarchical • Submission to superordinate goals • Hierarchical coordination • No necessity to share values and beliefs	**3. MARKETS** • Information widely diffused, no control • Relationships impersonal and competitive • No superordinate goals - each one for himself • Horizontal coordination through self-regulation • No necessity to share values and beliefs
UNSTRUCTURED INFORMATION	**1. FIEFS** • Information diffusion limited by lack of codification to face-to-face relationship • Relationships personal and hierarchical (feudal/charismatic) • Submission to superordinate goals • Hierarchical coordination • Necessity to share values and beliefs	**4. CLANS** • Information is diffused but still limited by lack of codification to face-to-face relationships • Relationships personal but nonhierarchical • Goals are shared through a process of negotiation • Horizontal coordination through negotiation • Necessity to share values and beliefs

Figure 3: business models by means of information and diffusion

3. Method

3.1 Introduction

We make a diagnosis of the functional and coordination competences of the present business model of Leden Electronics, a global operating corporation, which has geographically distributed branches in the USA, Europe and Asia, and therefore is heavily dependent on an appropriate coordination mechanism. Leden Electronics (a fictitious name of a multinational

[2] Also known as exploration (March, 1991), revolution (O'Reilly & Tushman, 1996) or alternatives such as dramatic change/quantum leap/metamorphosis, between change, discontinuous change and second-order change.

[3] Also known as exploitation (March, 1991), evolution (O'Reilly & Tushman, 1996), or alternatives such as concerted change/momentum/adaptation, within change, continuous change and first order change.

corporation) designs, manufactures and markets products for customers in industries ranging from automotive, appliance, aerospace and defense to telecommunications, computers and consumer electronics. Its innovation processes and employee turnover asks for the evaluation of their present functional and coordination knowledge sets. The research is conducted at the Engineering department of a major division CCC.

3.2 Competences

Firstly, the processes of the engineering department, divided over different stages, are monitored and mapped by means of the input from interviews with various employees (Sales, Engineering, and Management), internal planning software, internal quality system and a theoretical view of six sigma theory. We use the NPD approach for Takeuchi & Nonaka (1986) as point of reference for the stage-gate model and find the following stages: feasibility, justification, product concept, product design, tooling, introduction and production (see appendix I).

Secondly, we verify which knowledge sets that are needed to perform the actions in the different stages. We refer to these knowledge sets as competences, which are built up from capabilities, which in turn contain skills and assets. Employees are using their skills, and combine these skills with the present assets, in order to execute an action. The skills themselves are performed at the deepest (base) level.

Thirdly, the skills are categorized into a modular set of competences which are strongly related to each other. Nine groups show strong similarity with the formation of internal activities: the functional competences. Besides, six competence groups are filled with activities that did not contribute directly to the functional processes of the engineering department. Clearly, the coordination which originates from the coordination competences is covering all of the functional competences. However, coordination takes also place within each building bloc. Each building block exists of at least two functional entities and one coordination entity.

The study finds the following functional and coordination competences. Each competence is built up from capabilities which, in turn, exist from skills and assets.

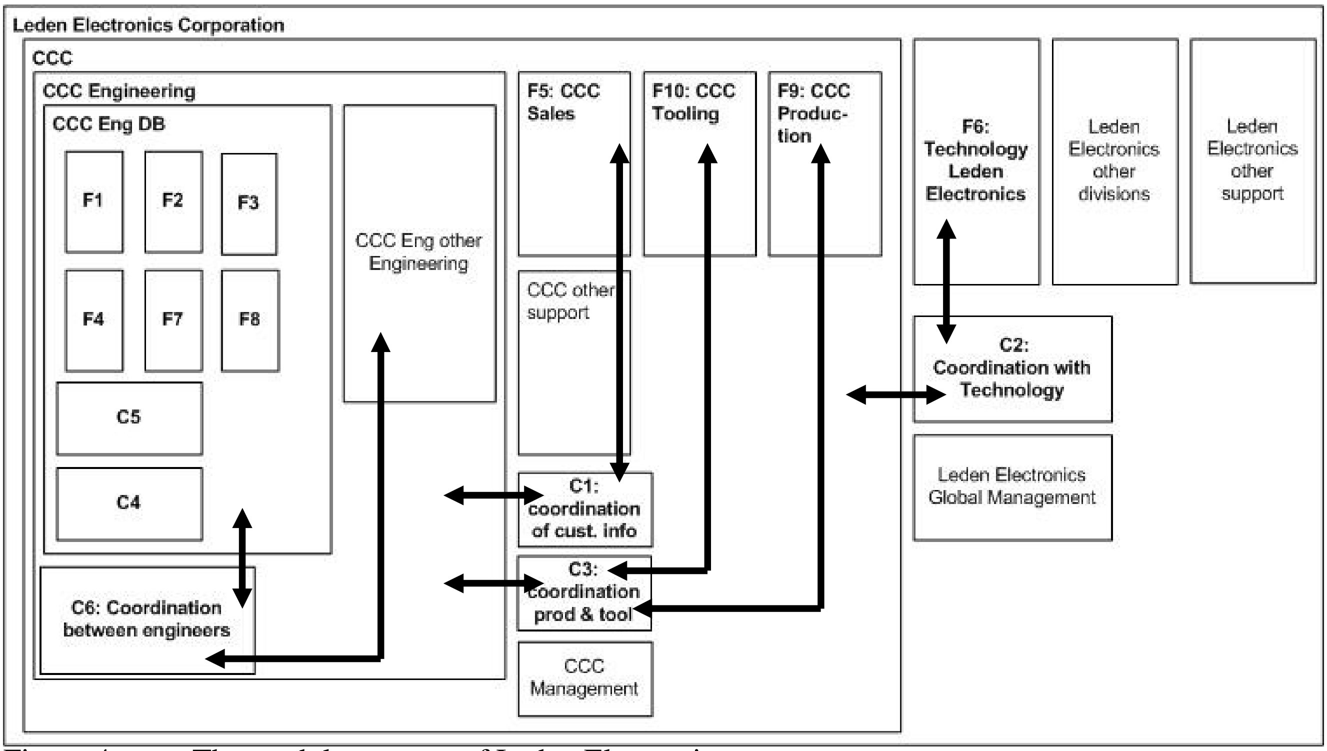

Figure 4 The modular system of Leden Electronics

- F1: Generate concepts: the ability to translate product specifications in concept solutions (Europe)
- F2: Select concepts: the ability to select concepts by means of customer needs (Europe)
- F3: Generate product design: the ability to translate a concept to a detailed product design (Europe)
- F4: Make/verify prototypes (create samples): the ability to create & test samples (Europe/China)
- F5: Sales: the ability to assess the commercial and technical value (Europe)
- F6: Technology: the ability to create new insights for later innovation (USA)
- F7: Process design: the ability to create relevant production processes as a basis for tool design (Europe)
- F8: Validation: the ability to validate the final product and process specifications (Japan/Europe)
- F9: Production: the ability to produce efficiently according to the specifications (China)
- F10: Tooling/manufacturing: the ability to create tools that meet product and process specifications (Japan)

The coordination competences refer to the coordination between engineers and other participants of the Leden production.

- C1: Coordination of customer information: the ability to coordinate the information flow between the customer and the engineering department (within Europe)
- C2: Coordination with Technology: the ability to coordinate between R&D and engineers (between USA and Europe)
- C3: Coordination with Production: the ability to coordinate engineering with tooling and production of this product (between Europe, Japan and China)
- C4: Coordination of Engineering department: the ability to coordinate the local engineering department (Europe)
- C5: Coordination of projects: the ability to coordinate projects (Europe).
- C6: Coordination between engineers: the ability to coordinate between engineers of different locations (Europe)

The level of decomposability is estimated as follows:

- Non-decomposable part: within the Engineering department the different competences do not have simple one-on-one relations with employees and activities in the various stages.
- Nearly decomposable parts:
    - Sequentially related subsystems of a business unit such as Sales, Engineering DB, other Engineering facilities, Tooling and Production.
    - Loose relations (codified output relations through benchmarks, strategic guidelines) between pooled subsystems such as different business units

3.3 The effectiveness of the competences

The employees of the company rank the competences in order to map the effectiveness (perceived added value and costs) of the competences. This is conducted by Delphi sessions with three groups of maximum fifteen employees each (Sales, Engineers and Managers).

All output from the engineering department in the various stages has specific properties on which the receiving stakeholder ranks the providing party. This rank represents the satisfaction of the receiver each property, known as receiver state parameter (RSP), a concept that is used in service management literature because of the difficulty to apply objective output measures for delivered services (Sakao & Shimomura, 2006). We have defined four groups that receive products/services from the engineering, namely Customers, Management, Production and the Rest of Leden such as tooling facilities. The RSP's per group are based on data from different sources:

- Customers: interviews with employees, a customer satisfaction survey, six sigma literature and the scoring factors that a main customer applies
- Management: their strategy map describes the goals which they set for coming year for the engineering department.
- Production: interviews with employees of the engineering departments and of interviews with factory employees.
- Rest of Leden: the quality aspects of information: accuracy, completeness and timeliness.

The Delphi sessions have been executed by three groups of experts (Sales, Engineers and Managers). The Delphi method is a systematic interactive forecasting method for obtaining forecasts from a panel of independent participants. The experts answer questionnaires in two rounds. After the first round, a facilitator provides an anonymous summary from the previous round as well as the reasons they provided for their judgments. Thus, the experts are encouraged to revise their earlier answers in light of the replies of other members of the group. It is believed that during this process the range of the answers will decrease and the group will converge towards the feasible answer. Finally, the process is stopped and the mean or median scores of the final rounds determine the results. The Delphi sessions were executed online. Each panel member uses a laptop to fill in online forms. The results have directly been given back as feedback to the group.

The groups have given their opinion about the added value and of the competences regarding group specific RSP's. The specific RSP's have been assigned to the groups that have the most insight and knowledge on it. The decision which RSP's had to be rated by which group was made in collaboration with the management of Leden Electronics.

Firstly the groups scored the competences individually, and then the groups arranged the competences in order of which competence delivers the most added value and costs to each one of the RSP's. For each RSP, the members of the group ranked the competences based on which competence contributes the most added value to the RSP. The 1st place is most added value and is scored with a 1. The 10th place contributes the least added value to the RSP, and is scored with a 10. After doing this for the three groups, the average of the scores of competences is taken in order to realise a list of which competence is the most important in creating added value to the engineering department.

Added value of competence ranked (1-10) by RSP	**RSP**									
	Management			Engineering			Sales			
Competence	*Generate new project revenue*	*Market share gains*	*Techno-logical leadership*	*Costing*	*Compe-tence*	*Timeliness information*	*Technology*	*Responsive-ness*	*Accuracy of information*	**Avg.**
0. Generate concepts	3,95	4,99	3,41	2,17	1,5	2,5	1,33	1,67	6	**3,06**
1. Select concepts	8,64	5,64	4,94	2	3,33	4	6,67	6	7,67	**5,43**
2. Generate product design	7,64	3,8	6,1	3	2,5	2,83	3,67	4,33	3,67	**4,17**
3. Create samples	6,94	5,6	6,93	5,17	5,67	5,57	4,33	4,67	7,33	**5,80**
4. Testing and validation	6,93	6,36	6,86	7	5,67	6,67	7,67	7	4,33	**6,50**
5. Coordination of production	6,38	8,44	8,36	7	7,5	6,67	6,67	9,33	8,33	**7,63**
6. Coordination of projects	5,31	6,27	7,71	5,17	5	4,67	6	4	3	**5,24**
7. Coordination of engineering department	4,71	7,73	6,84	8	8,67	8,5	7,67	7,67	7	**7,42**
8. Coordination of customer information	4,41	2,67	4,11	5,83	6,83	5,33	6	4	2,33	**4,61**
9. Adaptive ability	2,39	6,11	3,23	9,67	8,33	8,17	5	6,33	5,33	**6,06**

Table 1 The relative added value of competences

The groups then scored the competences again, now based on which competence costs the most by contributing added value to a RSP. The 1st place costs the most and was scored with a 1. The 10th place costs the least in contributing added value to a RSP, and was scored with a 10. This was again done for two RSP's each group (data from Sales are not available). After doing this for the groups, the average of the scores of competences is taken in order to realise a list of which competence costs the most in adding value to a RSP.

Costs of competence ranked (1-10) by RSP	RSP									
	Management			Engineering			Sales			
Competence	*Generate new project revenue*	*Market share gains*	*Techno-logical leadership*	*Costing*	*Compe-tence*	*Timeliness information*	*Technology*	*Responsive-ness*	*Accuracy of information*	**Avg.**
0. Generate concepts	4,16	4,7	4,4	4	2,83	2,5	n/a	n/a	n/a	**3,77**
1. Select concepts	6,8	6,19	6,01	9	7,33	6,33	n/a	n/a	n/a	**6,94**
2. Generate product design	3,56	4,29	4,73	2,5	2,83	4	n/a	n/a	n/a	**3,65**
3. Create samples	5,06	5,2	5,06	4,67	3,5	4,33	n/a	n/a	n/a	**4,64**
4. Testing and validation	5,16	5,38	5,01	4,83	5,17	6	n/a	n/a	n/a	**5,26**
5. Coordination of production	5,72	4,88	7,55	3,67	5,33	5,83	n/a	n/a	n/a	**5,50**
6. Coordination of projects	5,48	5,2	6,5	4,33	3,5	3,33	n/a	n/a	n/a	**4,72**
7. Coordination of engineering department	5,53	6,03	5,69	8,33	9	9,17	n/a	n/a	n/a	**7,29**
8. Coordination of customer information	6,8	5,99	5,1	5,67	6,5	4,83	n/a	n/a	n/a	**5,82**
9. Adaptive ability	7,21	7,38	5,31	8	9	8,67	n/a	n/a	n/a	**7,60**

Table 2 The relative costs of competences

Then, the scores of added value are inverted in order to get logical results which could be viewed in graph.

Competence	*Average Added value of competence ranked (1-10)*	*Average Added value of competence ranked (1-10) inverted*	*Average cost of competence ranked (1-10)*	*Load (Added value / cost)*
0. Generate concepts	3,06	7,94	3,77	**0,81**
1. Select concepts	5,43	5,57	6,94	**0,78**
2. Generate product design	4,17	6,83	3,65	**1,14**
3. Create samples	5,80	5,20	4,64	**1,25**
4. Testing and validation	6,50	4,50	5,26	**1,24**
5. Coordination of production	7,63	3,37	5,50	**1,39**
6. Coordination of projects	5,24	5,76	4,72	**1,11**
7. Coordination of engineering department	7,42	3,58	7,29	**1,02**
8. Coordination of customer information	4,61	6,39	5,82	**0,79**
9. Adaptive ability	6,06	4,94	7,60	**0,80**

Table 3 Added value, costs and loads of competences

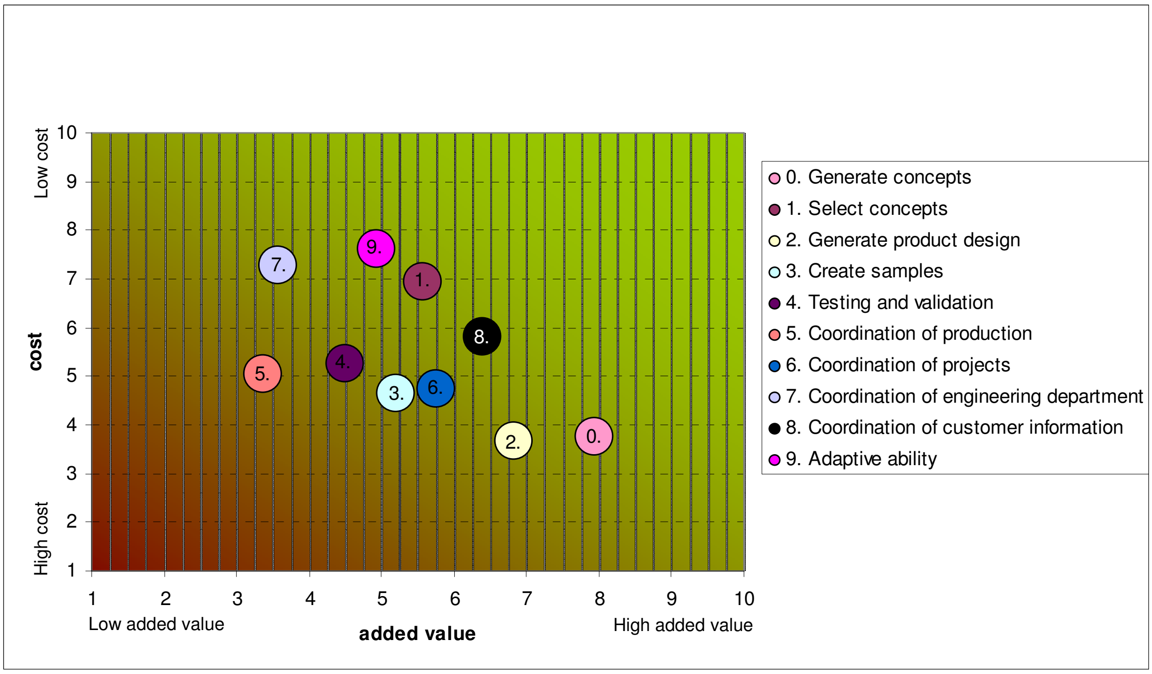

Figure 5 Perceived performance of competences

The red part (left and below) in the graph means a competence with a heavy load for the organisation. The green part in the graph (right and up) refers to low load competences. The main result is that number 5, the coordination of production (= C3: coordination of engineering with tooling and production) is under pressure.

3.4 New insights during data gathering

This perceived performance graph is one of the results of the preliminary stage of the study. Later in the study, we have added several competences, namely Process design (F7), Sales (F5), Tooling (F10), Production (F9), Technology (F6), Coordination between Engineers (C6) and Coordination with Technology (C2). Our latest observations have shown the relatively low added value of both coordinating competences at the moment – both are in a process of transformation. We have removed adaptive ability (9) from the list because the adaptation is realized by the recombination of competences as approved on a higher level.

3.5 *Measurement for the functional competences*

The diagnosis of the functional and coordination competences first requires an assessment of underlying functional and coordination skills. As stated before, we calculate the difficulty of functional competences (indicating their complexity and variability) by summarizing the difficulties of their skills.

The data has been elicited from of a set of interviews. These data are supplemented with regularly used forms and information obtained by observation. Each skill was scored on a scale from 1 (low) to 5 (high on complexity/variability). The complexity and variability were summarized to calculate the difficulty of each skill, which generated a range of scores varying from 2 to 10. This range has been divided into three[4] zones with corresponding colors:

- 2 - 4,9 → easy (green)
- 5 - 7.9 → hard (yellow)
- 8 - 10 → difficult (red)

In the results section, the data are listed in a matrix which provides an instantaneous overview of the different competences and their difficulties.

During the study, it became clear that same skills are performed for several capabilities and that in some cases, while the capabilities and competences differed, some skills were the same (the specific capabilities are not mentioned in this paper). Skills, present more than once in a competence, were only weighed once to make sure that the scores would reflect the difficulty of the competence (and not that of the capability). Similar skills used in different competences can be scored differently because they can (be provoked by completely different circumstances) involve completely different acts. The skill “Working together”, for example, is scored as *difficult* in the competence “Generate product design” and is scored as *hard* in the competence “Make and verify prototypes”. This is difference is made because working together in making a product design is a lot more complex (and does not occur a lot) than working together to make and verify the prototypes, because their working together is required to discuss the results of prototyping process.

Two researchers have studied and discussed the data in order to increase the reliability of the outcomes. A definitive list was created with the consensus both researchers.

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[4] The number three has been chosen in correspondence with the number of coordination methods.

After the scoring the skills within each competence, the competences have been listed in order of their difficulty. The overall average of the competence's difficulty and the distribution of the skill-scores provide a good view of that difficulty (see results section).

The result of each functional competence is based on the sum of Perrow's (1970) dimensions of the underlying skills. We have not paid explicit attention to the internal coordination of the individual competences, but we do take the coordination between the competences at higher levels into account. Therefore, we add a bonus towards the difficulty-measures based on the Thompson's (1967) interdependence scale between competences (and higher subsystems). This bonus (+2 for mutual relations; +1 for sequential relations; + 0 for interdependent subsystems) may results in the demand for more intensive integration.

Thereafter, the difficulties of functional subsystems at the next levels are calculated. Again, this is the mean of the original score (without the bonus) because the coordination competences will have solved the need for the interdependence. Consequently, on that higher level, again a bonus is added to the average complexity as contingency for the coordination on that level. We apply this procedure in order to prevent that deeper mutual relations contribute to the difficulty of the highest level.

3.6 Measurements for the coordination competences

Coordinative competences are the glue which "sticks" the functional competences together. They provide the necessary communication, exchanging of certain forms etc. etc. In short: they control the information flow between people and departments. Below, we introduce a range of coordination competences. In the theoretical section, we have explained our view on standards, routines and improvisation. Based on Grant (1996), we make a distinction between Standards (direction) and Routines. We add culture to standardization because it is an unobtrusive way of creating a desired effect (Perrow, 1986; Leonard-Barton, 1992). Finally we separate improvisation from routines because of the short feedback loops and their defining impact for discovering new insight (Moorman & Miner, 1998; Ciborra, 1999a).

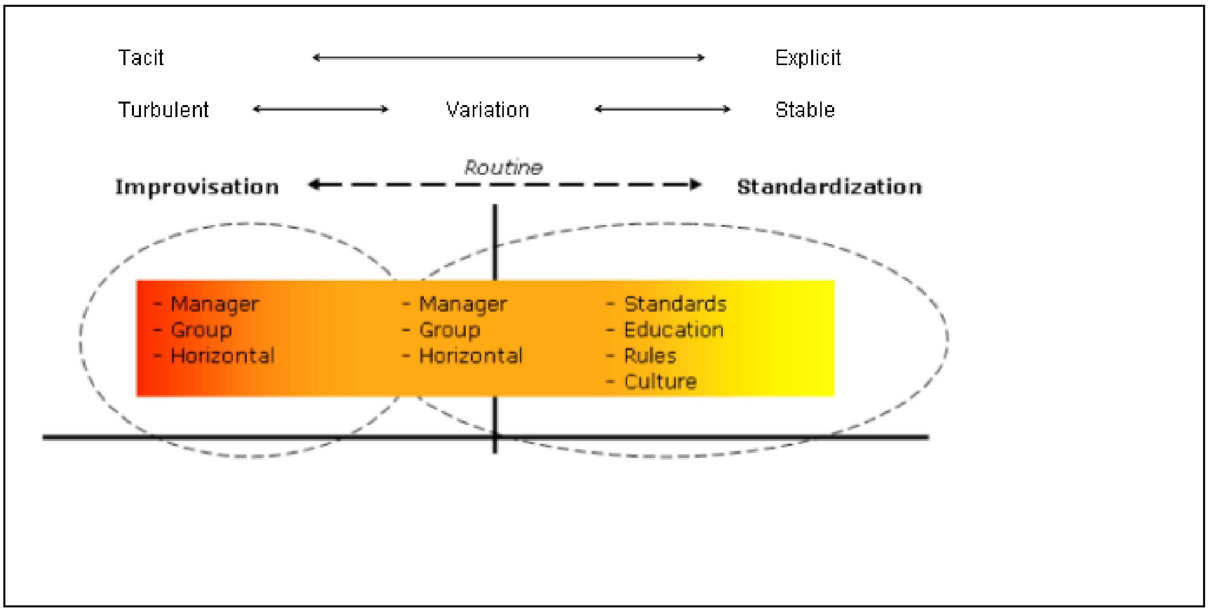

Figure 6 The range of coordination competences

Standards are based on codified data and appropriate for diffusions/autonomous cooperation, whereas improvisation uses tacit knowledge with conscious control (company or network). Structured, implicit routines are a more stable form of dealing with complex issues but still based on experience and intensive interaction during cooperation. They are used to bridge the holes between improvisation and standards.

The measurement of the coordinative competences requires a different approach than the functional competences, because for these competences it is not so much the difficulty that is important, but more the methods of coordination that are being used to "glue" the functional competences together.

The data needed to determine the level of coordination were elicited from the same interviews that were used to find the difficulty of the functional competences. These interviews lead to estimations of the methods used within these competences. To confirm these preliminary estimations, several other interviews have been conducted. This also made sure that no false assumptions were made. These interviews have been combined with observations and a scan for an overview of the communication, the standards and ICT-tools that are being used to fulfill the coordinative competences.

A range from 1 to 10 has been developed:

1. Very strong standardization
2. Strong standardization
3. Standardization possibly supplemented with routines
4. Standardization supplemented with routines
5. Routines supplemented with standardization
6. Routines supplemented with improvisation
7. Improvisation supplemented with routines
8. Improvisation possibly supplemented with routines
9. Strong improvisation
10. Very strong improvisation

3.7 Criteria for coordination

We start with the premise that within companies a multitude of coordination mechanisms are present. Following that, three rules are introduced for suitable coordination.

1. Matching the functional entities.

The complexity and variety of the functional entities within the modules, which indicates if the work is simple, hard/complicated or even difficult/chaotic, is a first indicator for the coordination of the module (Perrow, 1970; Snowden & Boone, 2007):

- Coordination within range 1-3 is appropriate for an easy functional competence (2-4,9);
- Coordination within range 4-6 is appropriate for a hard functional competence (5-7,9);
- Coordination within range 7-10 is appropriate for a difficult functional competence (8-10).

2. Level in the modular hierarchy.

Within a particular module, a comparable coordination score is needed for different coordination entities on the same level because system theory suggests that borders are defined where the intensity of interrelations change. The coordination between higher modules is more standardized because of the lower density of interaction between these subsystems.

3. Number of crossed borders.

If multiple borders are crossed, the involvement of additional subsystems forms an extra constraint so that mutual interrelations need to be decreased for effective coordination (or very complicated coordination competences need to be developed to relate competences of remote subsystems).

4. Results

4.1 Findings on functional competences

The results of the scoring process are presented in order of difficulty.

	Complexity	Variability	Difficulty
Generate concepts	**3,5**	**3,1**	**6,6**
Think of a new concept, work out an existing idea (creativity)	5,0	5,0	10,0
Set/recognize specifications	5,0	5,0	10,0
Creativity	5,0	5,0	10,0
Experience, common sense, working with your head	5,0	4,0	9,0
The ability to resolve problems	4,0	4,0	8,0
Knowledge	5,0	2,0	7,0
Gathering information	2,0	4,0	6,0
Being able to make choices	4,0	2,0	6,0
Communicational skills	2,0	2,0	4,0
The ability to convince	2,0	2,0	4,0
Thinking from a CAD-model/drawing	2,0	1,0	3,0
Modeling	1,0	1,0	2,0

Table 4 Competence F1 “Generate concepts”

“Generate concepts” has been scored as the most difficult competence. A lot of skills that are required are very complex, mostly because of the amount of tacit knowledge that is required to execute them.

“Think of a new concept, work out an existing idea” has the highest score on complexity and variability. This skill is very complex because it requires a lot of experience, understanding of the processes and the procedures cannot be written down. It scored high on variability, because the concepts are always different and require, for example new techniques and materials.

On the other end of the scale is “Modeling”; this is the ability to make a drawing of a component using a CAD program. This is scored as an easy skill, because once people know how to operate the program it is not complex, nor is there a lot of variation. When the average difficulty of 6,6 is combined with the distribution difficult, hard and easy skills and consequently is compared with the other competences, it is fair to say that this is the most difficult competence.

	Complexity	Variability	Difficulty
Generate product design	**3,0**	**2,8**	**5,8**
Judging/determining customer demands	5,0	5,0	10,0
Determine product demands (KPC)	5,0	5,0	10,0
Setting priorities (planning and organising)	5,0	5,0	10,0
Working together	4,0	5,0	9,0
Working accurate	5,0	3,0	8,0
Making design goals	3,0	4,0	7,0
Setting product specifications	3,0	4,0	7,0
Material- en product knowledge (technical execution)	5,0	1,0	6,0
Executing design validation	3,0	2,0	5,0
Communicational skills	2,0	2,0	4,0
Stuying information send by customer (e.g. demands)	1,0	2,0	3,0
Being capable to work with the required software	1,0	1,0	2,0
Creating design models	1,0	1,0	2,0
Developing drawings/sketches	1,0	1,0	2,0
Being able to work indepentently	1,0	1,0	2,0

Table 5 Competence F3 “Generate product design”

In comparison with “Generate concepts” the competence “Generate product design” has exactly as much hard and difficult skills, but two more easy skills. This results in a lower average of 5,8. Because the spread of the difficulties is essentially the same as the previous competence, “Generate product design” can be labeled as the second most difficult competence.

	Complexity	Variability	Difficulty
Make and verify prototypes	**2,9**	**2,8**	**5,7**
Monitor project status	5,0	5,0	10,0
Applying new technologies	4,0	5,0	9,0
Studying new technologies	4,0	5,0	9,0
Planning and organising	5,0	3,0	8,0
Setting priorities	5,0	3,0	8,0
Discussing projects	2,0	5,0	7,0
Technical understanding	5,0	2,0	7,0
Researching boundaries and limitations of design	4,0	1,0	5,0
Anwsering technical questions	2,0	3,0	5,0
Working together	1,0	4,0	5,0
Making a decision: do own prototyping or outscource it	2,0	2,0	4,0
Gathering information	2,0	2,0	4,0
Product- and machine related knowledge	2,0	2,0	4,0
Technical skills	2,0	2,0	4,0
Communicational skills	2,0	2,0	4,0
Being able to handle tools and equipment	2,0	2,0	4,0
Communicating testresults	2,0	1,0	3,0
Overview of processes	2,0	1,0	3,0

Table 6 Competence F4: “Make and verify prototypes”

The competence “Make and verify prototypes” has skills that can be acquired through education or transferrable (explicit) knowledge. Those skills have been awarded a lower complexity score, because they are easy to obtain. Many of those skills also have a low variability score, which results in an easy difficulty. As the distribution of the color shows, the difficulty scores of this competence are primarily in the easy and hard zones. This fact combined with the same amount of difficult skills, makes this competence the third most difficult.

	Complexity	Variability	Difficulty
Select concepts	**3,1**	**2,4**	**5,6**
Combining strengths of different concepts	5,0	4,0	9,0
Weighing (dis)advantages of certain concepts	4,0	4,0	8,0
Possession of required knowledge	5,0	2,0	7,0
Convincing abilities	3,0	2,0	5,0
Customer contact, giving customer liberty of choice for a concept	2,0	2,0	4,0
Weighing specifications	1,0	2,0	3,0
Gathering information	2,0	1,0	3,0

Table 7 Competence F2 “Select concepts”

“Select concepts” is scored as the second to easiest competence. Part of the reason is that none of the skills scores the maximum of 5 points for variability.

	Complexity	Variability	Difficulty
Validation	**3,2**	**1,6**	**4,8**
Interpretation of testresults	5,0	5,0	10,0
Planning and organising	5,0	2,0	7,0
Setting priorities	5,0	2,0	7,0
Giving a recommendation of a test method	4,0	2,0	6,0
Being able to handle tools and equipment	4,0	1,0	5,0
Technical knowledge (product knowledge)	4,0	1,0	5,0
Knowing how to perform a test	4,0	1,0	5,0
Communicating (with other laboratories)	2,0	2,0	4,0
Working accurately	3,0	1,0	4,0
Determining whether a request can be granted or not	2,0	1,0	3,0
Understanding of the process	2,0	1,0	3,0
Calibrating measuring equipment	1,0	1,0	2,0
Making a test report	1,0	1,0	2,0

Table 8 Competence F8 “Validation”

Only one skill was scored as difficult in the competence “Validation”. Although quite a lot of skills scored high on complexity their variability is low. That means that experience and tacit knowledge is required to able to obtain the skill (and perform the competence), but that the work does vary a lot. This makes “Validation” the least difficult functional competence within the engineering department of Leden Electronics in the Netherlands.

4.2 Estimated results for higher functional subsystems

The mean score of CCC ENG DB is 5,7 (average without competence F7 = process design). On this level, there are reciproque relations between F1-F4 and F7-F8. The coordination competences within CCC DB have to deal with difficulty of a 7,7 (average + 2 bonus for mutual relations).

The other subsystems have not yet been measured, but some first estimates are the following (based on observations and conversations.

- A 5,7 is also assigned (as a first estimate) towards CCC ENG other Engineering. Therefore CCC Engineering as a whole receives a 5,7. Because of the sequential nature of the contacts between the different CCC Engineering locations, the coordination competences within CCC need to meet a difficulty of 6,7 (average +1 bonus for sequential relations)
- CCC Sales is more dynamic than CCC Engineering, so we estimate it with a 6. CCC Tooling is slightly less hard and receives a 5,5. This is even more the

case for CCC Production so it receives a 5. The average of the division (or business unit) CCC is therefore a 5,6. The management of CCC needs to react to a difficulty of 6,6 (average +1 bonus)

- Other Leden Electronics divisions receive an estimate of 5,5; they are in the same league although somewhat smaller. Technology (conducting R&D) receives a 6, 5 and other supportive units receive a 5,8. Therefore Leden Electronics finishes with a 5,8 (average without extra bonus: pooled), which is also the difficulty that Global management needs to deal with. So their (complex) task is to define structured goals in order to integrate the different business units.

These first results show an expected decrease of complexity at higher levels of the system, so that embedded coordination becomes an opportunity, whereas deep within the system routines (supplemented with improvisation) is required.

4.3 Findings on coordination competences

The coordinative competences are listed from most improvised to most standardized.

C1: Coordination of customer information	
Standards	*Ways of communication & ICT-tools*
RTS TAR PFR EPM	Face-to-face E-mail Telephone (conference calls) NetMeeting Video conferencing (start-up phase)
6 Routines supplemented with improvisation	

Table 9 Competence C1 "Coordination of customer information"

The coordination between Sales and Engineering receives a 6. This is possible because the local director of the Engineering group and the participants of with Sales are situated in the same building. So when Engineering (or Sales for that matter) has a problem or a question they simply walk to the adjacent office and discuss the issue. For less pressing issues they send an e-mail or make a telephone call. When the customer requires contact with the Engineering department (before the definitive order has been given), they most regularly use conference calls. In the future some conference calls will be replaced by video conferencing. Video conferencing will most probably also replace NetMeeting.

To coordinate they use routine that consists of standard forms (RTS, TAR etc. etc.) and ad hoc communication. But when one of the two parties need more information or a crisis situation arises they rely can on improvisation to quickly resolve the issue.

C5: Coordination of projects	
Standards	*Ways of communication & ICT-tools*
Design FMEA	Face-to-face
Process FMEA	E-mail
Drawings	Telephone (conference calls)
ECF	NetMeeting
EPM	Video conferencing (start-up phase)
6 Routines supplemented with improvisation	

Table10 Competence C5 “Coordination of projects”

Coordinating the projects is task of the project engineers in collaboration with the engineering managers. They maintain, e.g. the project planning (EPM) and the quality of the drawings, through standards. Coordination of the engineers is primarily conducted by face-to-face contact. Contact with customers or resident engineers are maintained by e-mail and telephone. NetMeeting is (almost) not being used anymore; this has been replaced with video conferencing. This form of coordination can be marked as a routine. In cases where fast response is required they can rely on improvisation, which is made possible by the short communication lines, the informal culture and the fact that is an operational competence.

C4: Coordination of engineering department	
Standards	*Ways of communication & ICT-tools*
TAR	Face-to-face contact
FSR 1 (verification) + 2 (validation)	Monthly meeting with groupleaders
PCS	Weekly work meetings with Engineering Managers
FTAR	Townhall meetings for all employees
SAP	Contact with sales about certain products
Quality manual	Being involved by sales in conversations with customers
Procedure Tool & Process Specification	Telephone (conference calls)
Process (Quotation and Process database)	E-mail
Project administration	NetMeeting
	Videoconferencing (start-up phase)
5 Routines supplemented with standardization	

Table 11 Competence C4 "Coordination of engineering department"

This competence is being fulfilled by the local director of the Engineering group. During the weekly meeting with the engineering managers the director is being updated on the status of the several projects. This meeting also gives him the opportunity to make crucial decisions and to manage the project in different directions. This is a clear example of coordination by routines. That coordination is being supplemented by the standard forms that, for examples, are being received from sales with a new order (RTS).

C3: Coordination of production & tooling	
Standards	*Ways of communication & ICT-tools*
EPM TAR FSR MSA PCS RDS FTAR *PPA (under construction)* First Article Inspection Template P-FMEA	Difficult communication (language and cultural differences Travelling (pure improvisation, predefined rules do not apply) Telephone (conference calls) Lots of e-mail contact (1100 e-mails per project) Video conferencing (start-up phase)
3 Strong standardisation (with additional improvisatory efforts)	

Table 12 Competence C3 “Coordination of production & tooling”

Coordination between Engineering, Tooling and Distribution takes place in a globally-dispersed context. So far, standardization is the main device for coordination. At the moment, the coordination with the Tooling and Production locations are mainly performed through standards; sending forms back and forth with requirement, approval rapports, test results etc. When Production was still located near the Engineering department, this proved to be a good method. Engineering would send forms to production and if production had any questions or problems, an engineer would walk to the production hall and answer the question or solve the problem. But since Production has been relocated to China (for the mobile phone division) it has become impossible for an engineer to simply “drop by” Production to help them solve problems. It is not only the enormous distance but also the cultural differences which prove to be problematic. At the plant in China there are only a few people who speak English and are able to fill in the forms or have a conference call. Together with the fast turnover of staff in China, this means that a lot of time is lost in explaining procedures and getting the information to the right location.

These problems make coordination by standards very difficult. That is why a project engineer (or engineering manager) travels to the Production (or Tooling) location several times during a project. When he is present at that location, he has to rely on pure improvisation to solve the problems, because on the one hand he does not have the direct support of his engineering team (the different time zones) and, because of the fast turnover of staff, he often has to get acquainted with new people that he has to work with.

C6: Coordination between engineers	
Standards	*Ways of communication & ICT-tools*
	SDP Engineering Forum Re-use database Operational Excellence groups
3 Strong standardization (with additional improvisatory efforts)	

Table 13 Competence C6 "Coordination between engineers"

Currently the coordination between engineers is very standardized. When looking at the list above this might seem as an odd finding, because it shows no standards. This competence facilitates the knowledge transfer between engineers of different locations, and for such a function no standard forms can be used. The reason for the strong standardization is the way the available databases are being used. The three databases can all provide information to a product- or development engineer, but most engineers only use one of them. As a result of that most engineers miss out on 2/3rd of the available information and often need to "reinvent the wheel". Because there is no regular communication between the several Engineering locations, no new methods or techniques are being discussed although managerial efforts are spent in order to structure the databases and their access. Since two years, an annual 'Technical Conference" has been organized where new developments and techniques are presented. But one annual event is not sufficient to change the score in the direction of a routine based coordination method.

C2: Coordination with technology	
Standards	*Ways of communication & ICT-tools*
Roadmaps from customers Re-use design features Literature EPM	Direct customer contact Short lines with Engineering department Difficult two-way communication (Technology - Industry platform)
Expected: 3 Strong standardization (with additional improvisatory efforts)	

Table 14 Competence C2 "Coordination with technology"

4.4 Diagnosis: applying the criteria for coordination

	Present		Required
C1: Coordination of customer information	6	→	6

F1-F4 (6,6- 5,6-5,8-5,7) relate with Sales (6), which results in a 6,9 difficulty (average 5,9 + 1 bonus). Therefore C1 (6) requires a bit improvisation although the emphasis is routine coordination. One border is crossed, which decreases the opportunity for elaborate improvisation.

C2: Coordination with technology	3	→	5

C2 coordinates, on the individual level, between F6 (6,5) and F1-3 (6,6 + 5,6 + 5,8). The difficulty to deal with is 7,1 (average 6,1 + 1 bonus). Routines (5) are sufficient because improvisation is not useful in the context of several related business units / divisions (several borders need to be crossed). Transparency is a key determinant of success: working procedures (who has access, who delivers input, who applies the output) to lower the search costs and clear cost-benefit ratio on the level of the individual person.

C3: Coordination with production & tooling	3	→	5

F3-4 and F7-8 (5,8-5,7-?-4,8) relate with Tooling (5,5) and Production (5). Their difficulty is 6,4 (average 5,4 + 1 bonus). Therefore C3 needs to have a score of 4-6. It functions on the same level as C1 (6) so it needs a score close to 6. One border is crossed, which decreases the opportunity for improvisation. Therefore, we rate C3 with a 5.

C4: Coordination of the engineering department	5	→	5

As stated before, on this level, there are reciproque relations between F1-F4 and F7-F8. The coordination competences within CCC DB have to deal with difficulty of a 7,7 (average 5,7 + 2 bonus) and receives a 5. It is on the same level as C5 (6) but because most of the situations that require improvisation are handled by the operational competence C5.

C5: Coordination of projects 6 → 6

This coordination competence meets the same functional competences (7,7) as C4 (5). It has more improvisation because of its operational issues so it receives a 6.

C6: Coordination between engineers 3 → 6

C6 coordinates between two subsystems with 5, 7. The difficulty it has to answer is 6,7 (average 5,7 + 1 bonus). Improvisation between engineers of different Engineering department is possible, but because of the distance (different countries in Europe are involved), management is setting up systems, which are not yet functioning.

The required values are based on the three criteria (match functional entities; same level, borders crossed). C2 is relatively low because of border crossing. C4 might have been higher but can be dealt with in structured way.

The causes for the low added value against average costs of C3 (number 5 in Figure 4) is the fact that its coordination is too standardized where it should be routine, in line with C1, which however has the local community at its disposal.

Later conducted interviews show that the coordination with Technology (C2) en coordination between Engineers (C6) are also under pressure. C2 needs to transform the one-way and top-down information flow towards more flexible two-way routines. C6 is too standardized at the time. Routines for transparency and options for slight improvisation would be beneficial. A community of practice (CoP) could be an option (see Discussion). This involves much interaction, learning by sharing but without the direct request for codification (Hildreth, Kimble & Wright, 2000).

5. Conclusion and Discussion

5.1 Conclusion

In this paper we combine innovation, the preservation of knowledge and appropriate coordination based on the view of organizations as modular systems with changing levels of decomposability (Nickerson & Zenger, 2004). Based on this view, a variety of coordination options is available for organizations, so that a typology based on standardization versus improvisations becomes less relevant. It is the reach of different improvisation (inside out) or standardization (outside in) that matters.

So far, Leden Electronics has not fully exploited this variety of coordination options. We find that the coordination between engineering, tooling and production (C3) of Leden Electronics demonstrates relative low added value. The comparison of C3 with the three coordination criteria explains why it has low perceived level of added value. Standardization is so far the main device for relating the three globally dispersed subsystems. Technology is not yet used/able to 'translate' implicit information to explicit information (Nonaka, 1991), so that additional face-to-face efforts are needed to transfer implicit knowledge. Implicit routines to blend this improvisation with present standards are not yet pervasive.

We view comparable flaws at the coordination with Technology (C2) and the coordination between engineers (C6), as has already been observed by the management of Leden and has become subject of change processes. Although databases to store engineering data are present and working, the variety in their working procedures (who has access, who delivers input, who applies the output) leads to a lack of transparency. This generates questions about the time needed for the quest for relevant information and about the rewards for investing time for advantages at other locations of Leden. For instance, as long as time spent by engineers to re-use design features, which may be profitable for other subsystems tooling and production, is not related back to reward Engineering, then engineers tend to consider this spent time as costs, and not as Leden relevant investments.

This lack of appropriate coordination routines does not support the preservation of knowledge in routines; a dangerous situation in the face of employee leave. Furthermore, the diffusion of present improvisations is limited and only available for the direct involved persons as long it does not concern codified data. Therefore Leden denies itself innovations by means of recombinations of routines, in which other parts of Leden share, and the space for innovation by new improvisations because the employees are too busy with supporting the standards.

5.2 Discussion

We suggest, where possible, a transformation for improvisation towards routines. This move would support better coordination and encourage the conservation of knowledge because routines are based on teamwork (see appendix II). If an employee leaves the team and new colleagues arrive, the previous routine transferred by working on the job, exchanging experiences and so on. The new videoconferencing system is a very useful tool to create routines because it enables more regular contacts. Nonaka (1991) also describes the process of externalization to ramp up non-codified routines toward codified standards to the extent that specific non-codified information can be made explicit.

This approach will support the distribution of existing knowledge (routine based on collaboration within teams in which globally distributed stakeholders share) and creates space for new improvisation. The former may support innovation the recombination of Leden routines and the latter allows for new mutations, caused by new ideas from experienced employees and/or by contributions from new colleagues to prevailing routines (Becker et al., 2006).

Managing the dynamics and balance of different coordination options within the modular system is an instrument for organizations, which participate in networks, to control their contributions and live up to their reputation. As stated before, their reputation and identity depend on the opportunity to transform their improvisation to routines (and standards when possible). ICT and a corporate culture have a vital role to create a new set of coordination routines. Ciborra (1999b) refers to the culturally-aligned ‘hospitality’ concept to adopt the technology as (non-human) stakeholder. By doing so, he introduces the relevance of 'hosting' properties to blend the knowledge sets of various stakeholders. Key elements are the removal of the language of planning and the introduction of multinational disciplinary teams. These teams participate and learn by processes of bricolage (combining building blocks), tinkering (trial- and-error), the acceptance of mutual differences without abolishing their cultural borders, and improvisation to overcome resilience.

Saccol & Reinhard (2006) continue upon Ciborra’s view by referring to communities of practice (CoP), where people have the opportunity to learn and innovate as basis for improvisation (Brown & Duguid, 1991). Especially for the moulding of innovative virtual communities, a hospitable environment is necessary. Employees need a ‘psychological free haven’, a ‘sense of sanctuary’ or a ‘zone of immunity’ before they successfully may deviate from their previous knowledge and experiences as stored within routines (Gibson & Gibs, 2006; Breukel & Go, 2009). This hospitality paradigm may be a useful concept to support the expansion of local CoP towards a globally stretched CoP as a way to create globally collaborating teams (Hildreth, Kimble & Wright, 2000; Pan & Leidner, 2004).

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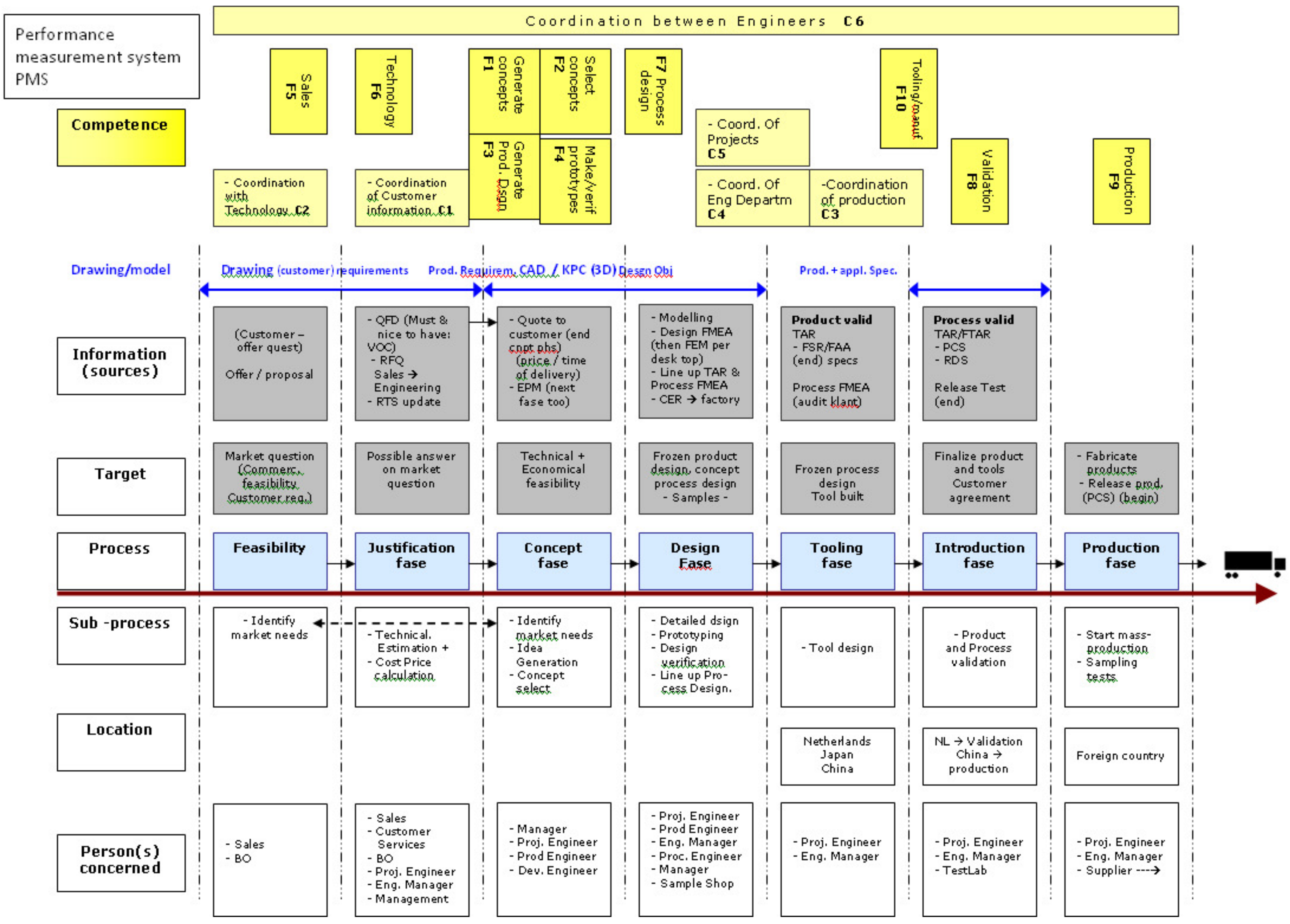
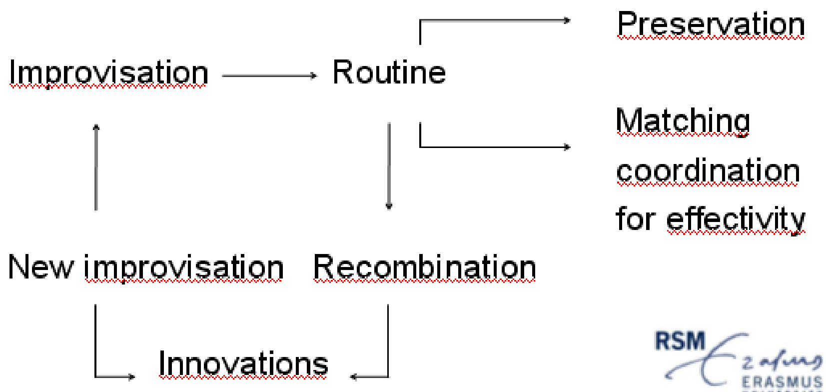
Appendices



I New Product development: Stages and competences



II	Absorption of previous improvisation in routines: impact for preservation, performance and innovation