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DESIGN FOR CONVERGENCE: MANAGING TECHNOLOGICAL PARTNERSHIPS AND COMPETENCIES ACROSS AND WITHIN INDUSTRIES

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1 Introduction

In recent trends of industrial dynamics and technological change, the effect of technological convergence can be observed as a major reason for disruptions, shake-outs and other reconfigurations of the competitive landscape. The convergence phenomenon is driven by a global dispersion of involved resources, an increasing amount of technological intersections and unifying disciplines, resulting business opportunities for collaborative design and innovation, as well as the sustained customer demand for full solutions and service provisioning. As a result, the convergence phenomenon implies the deconstruction of existing value chains, transforming industry boundaries and creating new competitive spaces. Facing an endangered value proposition, actors in converging environments have not only to tackle the deconstructed, diverged landscape by opening-up their proprietary innovation processes in both horizontal and vertical perspectives. They also have to support the co-creation of knowledge, and sharing future-oriented activities for generating creative disruptive responses on an inter-organizational basis.

From a design perspective, convergence has to be considered on both strategic and operative levels. Whereas operative actions should be based on an insight on the implications on design and engineering processes for products and solutions, strategic challenges consist of the management of technologies, competencies and partnerships. A profound understanding of drivers, characteristics and effects of technological convergence can serve as a basis for tackling the balance between strategic and operative issues in this context, and hereby represent a basis for deriving conceptual management models.

This paper will discuss the notion and the implications of the phenomenon of technological convergence and interdisciplinary innovation (section 2), deriving managerial challenges both in terms of strategic aspects (section 3.1), as well as operative issues (section 3.2). In particular, the importance of dynamic capabilities as a common ground for integration and networks is highlighted (section 3.3). Based on two underlying cases, related observations from both the information and communication technologies (ICT) sector as well as the area of mechatronics will be introduced (section 4), providing a basis for deriving management responses for design and innovation practices.

2 Convergence and interdisciplinarity

Technological convergence can be observed as an emerging effect of discontinuous innovation in a globalized industry. This effect is especially driven by the omnipresence of product components in a worldwide market, innovation opportunities based on an increasing amount of intersections and interfaces among technological solutions, business opportunities for establishing innovation collaborations, and in some cases, the customer need for full solution and service provisioning.

Concerning the two industry areas of information and communication technologies (ICT), as well as mechatronics engineering, the convergence of technologies has been a broadly observed trend [4, 8, 10, 16, 22, 40, 50, 74]. On the one hand, in the case of ICT, the convergence can be seen in the fusion of information and computing-oriented technologies with telecommunication systems. On the other hand, the on-going technological convergence in mechatronic products can be observed as a synergistic integration of mechanical engineering, electrical engineering, and software engineering. Generally, the convergence phenomenon can be classified into technology and business model convergence [36], which not necessarily have to be interdependent trends [27]. Similarly, the distinction can be made between technological and economical factors driving convergence through confluence, where technological factors consist in the evolution of communication and information technologies. On the other hand, the key economical factor can be seen in the worldwide liberalization of telecommunication markets [16], where convergence is enabled through deregulation [48, 67, 68]. In many cases, the effect of technological convergence can be observed as the collision of existing business models [28, 61], i.e. the sudden inter-firm overlapping of existing technological solution concepts, causing an accelerated competitive environment. In other words, due to the rapid changes in this high-tech sector, current technological solutions and even entire business models can be rendered obsolete within a short time. In general, the driving force of technological convergence can be seen in competition, where the need for new, convergence-based solutions is arising in parallel to the evolution of enabling technologies [23]. This resulting business need causes a market-pull towards convergence, in parallel to the technology-push initiated by the technology development [36]. In a more long-term context, it is furthermore argued that technological convergence causes challenges for standardization organizations [66] and can be responsible for reshaping entire markets [2].

Nevertheless, convergence of technologies is an effect not only occurring in recent industrial trends. The phenomenon was in literature for the first time observed in the industrialization process in the USA, and in particular, in the machine tool industry during 1840-1910, where apparently unrelated industries “from the point of view of the nature and uses of the final product became very closely related” [63, 64]. As technological, and on a more generic level, industrial convergence in many cases implies a deconstruction of the value chain, i.e. vertical disintegration [59], existing products and solutions might get exposed to new competitive environments [7, 33, 53, 54, 58, 65, 73]. This disruptive effect on competition can be differentiated by convergence in substitutes, being characterized by different firms developing “products with features of certain other product”, and convergence in complements, occurring when “different firms develop products or subsystems within a standard bundle that can increasingly work together to form a larger system” [33, 34].

Furthermore, the emerging obsolescence and substitution of technologies has already been identified as a common phase in the technology evolution process [12], even though it was not originally and explicitly associated with technological or industrial convergence. Transferring this technology life cycle based view further to this case, technological convergence could be interpreted as the fusion of several incremental or sustainable technologies, which in their confluence achieve innovation with highly disruptive character [38, 42].

3 Implications and managerial challenges

3.1 Strategies for converging environments

In literature, convergence has so far been discussed mostly from a more technical perspective [10, 14, 15, 23, 40, 57]. Strategic aspects of such convergence, however, such as implications on business models [22, 26, 58, 61, 65], on management practices [9, 16, 22, 36] and on approaches for fostering disruptive innovation through interdisciplinary innovation [38, 44] can still be seen as rather rarely identified subjects. From an entrepreneurial and innovation management perspective, this issue deserves further attention in research, taking the technological convergence management challenge onto a generic level, developing theories not solely valid for single industries. This identified challenge for current innovation management formulates a research need for developing strategic management tools, allowing entrepreneurial planning and technology management for sustaining the competitive advantage of actors in converging environments.

Special focus has to be laid onto the resulting impact in terms of business model convergence, where creative destruction might lead to severe disruptions in the competitive environment [1, 6, 52], posing a need to collaborate along the value chain [5]. The effect of business model convergence can be either technology or market driven, implying needs to open-up innovation activities and acquire future competencies along the value chain. Figure 1 attempts to depict both market and technology-driven convergence tendencies along the value chain framework, both eventually implying entire industries to converge in the long term. In particular, for involved players in converging environments, the decision to integrate competences and technologies from external sources does not necessarily come as a strategic choice; it is regarded rather as a required operation in order to avoid negative effects of emerging shakeouts. In this context, technological convergence can be regarded as a special case for technology acquisition, combining the challenges of managing technological change on the one hand, and tackling disruptive innovation on the other hand [45, 49].

The managerial challenge is on the one hand based on the question of how to avoid fatal consequences such as business model obsolescence and market shake-out through predicting convergence. The notion of competition for industry foresight denotes "to gain a deeper understanding than competitors of the trends and discontinuities – technological, demographic, regulatory, or lifestyle – that could be used to *transform industry boundaries* and *create new competitive space*" [39], which definitely is the case when convergence occurs.

On the other hand, the resulting challenge consists in the avoidance of competitive failure and shake-out, once convergence has occurred. In other words, the latter perspective would refer to the question of how to minimize the negative implications at later stages (if it is not too late). In this context, it is especially interesting to observe what goes wrong for some industry actors, i.e. examining a special case of the innovator's dilemma, occurring when new technologies cause established, large firms to fail.

3.2 Integration as an operative response to technological convergence

According to Engwall et al. [25], there are demands for integration in various dimensions in product development. Examples of such are between different companies, between different departments, between various competencies, between different simultaneous projects, and between successive projects drawing on the same resources.

Various literatures in product development research [17, 56] refer to cross-functional integration as communication or interaction, where information exchange and physical meetings relate to the relationships between organisational functions. An increased information flow would be favoured to promote interdepartmental unity. In addition, other literatures refer to collaboration when they discuss integration, i.e. efforts that encourage collective goals and mutual respect through teamwork [47]. Integration is also referred to as a composite structure where both interaction and collaboration are in unity [46, 56]. The latter suggestion of integration implies that interaction is needed in order to reach collaboration, and it is proposed that collaboration will slowly emerge from interaction activities [43]. One common aspect for all views is that they all stress the crucial interface between human and organizational systems in new product development (NPD) activities [31].

With respect to mechatronics engineering, integration may refer both to interaction and collaboration that involve two or more parts (which enables them to work more effectively together) in a organisational perspective, and also in a product perspective as a mechatronical system is per definition [40] the synergistic integration of mechanical engineering with electronics and intelligent computer control in the designed manufacturing of industrial products and processes.

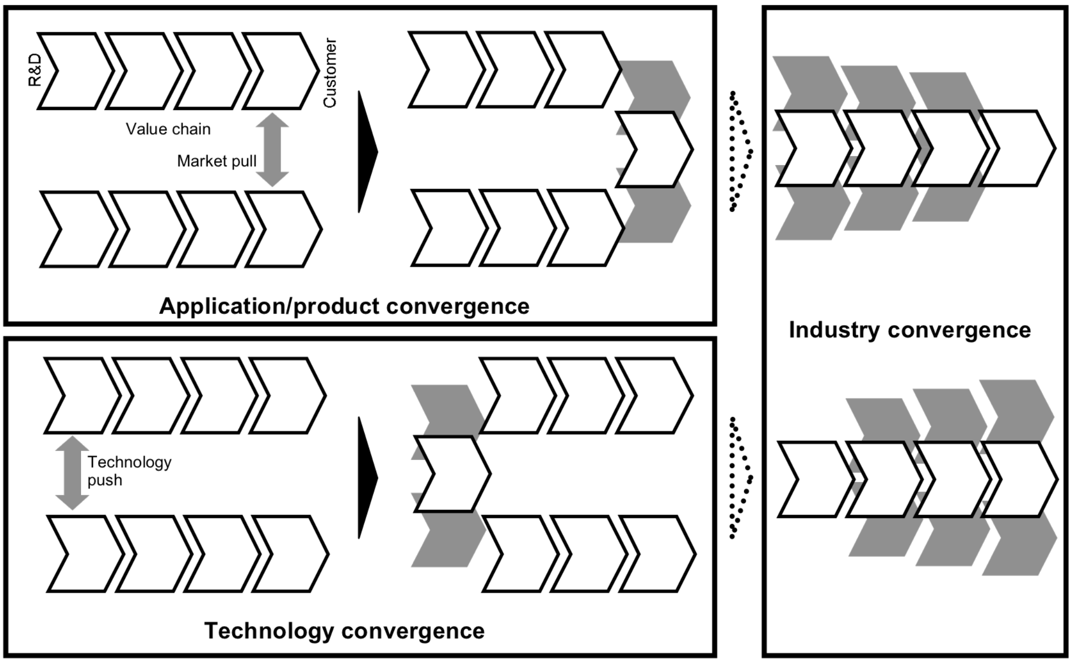

Figure 1. Sources of creative destruction through convergence

3.3 Dynamic capabilities, integration and value networks

In the dynamic industrial and market environment evoked by the convergence paradigm, firms' strategic responses also have to be built on flexibility. Therefore, the dynamic capabilities model [70] can serve as a suitable reference framework for considering the convergence from a strategic management perspective, aiming to align developed theories and models within the suggested "specific strategic and organizational processes like product development, alliancing, and strategic decision making that create value for firms within dynamic markets by manipulating resources in to new value-creating strategies" [24]. The dynamic capabilities framework represents a rational strategic management approach for the challenge of converging industries, as it serves to "integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" [70].

Targeting the development of such capabilities, one can distinguish between several cooperation strategies in response to technological convergence, where the differentiation is based on a value chain oriented view [35]. Such strategies can be categorized as the following [35]:

Horizontal. Industry actors within the same phase of the value chain, being positioned currently or potentially in mutual competitive relationships, initiate collaborative activities, in most cases aiming at optimizing costs.

Vertical. Collaborative activities among actors from different phases of the value chain are initiated, aiming at securing long-term relationships to customers and suppliers, thereby sustaining procurement tasks and distribution channels.

Diagonal. Collaborative activities are initiated among industry actors from different phases of the value chain and different industry sectors. In such a scenario, actors are not positioned in any direct customer-supplier relationship, aiming at e.g. implementing large-scale projects with investors from other sectors.

Complementary, network-oriented. This strategy is based on the customer demand for full solution provisioning instead of components supply, rendering it rather impossible for single market participants to deliver all subsolutions autonomously. Collaborative activities with complementary value generation partners, also known as (value) networks, provide preconditions for flexible action-taking, reduces risks and improves competitiveness on a sustainable basis.

Being identified as one dimension within the dynamic capabilities framework, the issue of initiating, implementing and managing such collaborative innovation is a crucial challenge. As convergence implies existing value chains to be deconstructed, the reconstruction and redefinition of value generation constructs has to be based on interfirm operations, i.e. one major management implication can be seen in an increased need for cooperation and network formation [18, 19, 22, 41, 60, 62, 71]. It is considered as not sufficient, to solely develop an understanding of the dynamics of industrial value creation processes along a deconstructed and converging value chain. Furthermore the challenge is perceived in a successful focus on the entrepreneurial competence portfolios based on the underlying heterogeneous set of firms, representing key focal points of a value-oriented convergence strategy (since competencies and core competencies represent the basis for value creation and competitive advantage of a firm) [62].

Based on these given circumstances, firms have designed new research and development (R&D) practices, including both internal organizational changes and the construction of complex networks to deal with growing outsourcing and various types of technological partnerships. This development is strongly supported by economic and social globalization, paving the way for worldwide competence complementation. Research on the specific characteristics of R&D cooperation in high-tech sectors exist [55], and these observations, together with new studies strive to construct a network model. The research activity area of R&D networks *in general* shows a wide range of contributions [13, 21, 29, 32, 55, 72]. From an operationalized perspective, the assessment and selection of strategic innovation partners shall be mentioned in this context [37].

In particular, a value network *per se* can be regarded as "the context in which a firms identifies and responds to customers' needs, solves problems, procures input, reacts to competitors and strives form profit" [20], referring to a rather static construct. Based on this background, one can argue that a strategic network-oriented positioning alone is not sufficient for being at the edge of innovation. Intersectional innovation requires firms to open-up even existing value networks into broader perspectives, allowing even newer opportunities for the creation of disruptive innovation [38, 44]. Whereas a continuous expansion and breaking-out of value networks allows firms to gain a strategic stake in emerging technological convergences, actors who tend to rather stay in static value networks – typically large, established organizations – will only possess potential for directional or incremental innovation. “This ultimately leaves such firms open to attack from upstarts that can innovate past them.” [44]

Based on the complementary, network-oriented cooperation strategy, Götte [35] argues that strategic networks are based on long term-oriented, contract-based relationships, whereas operative networks consist of rather short to mid term-oriented relationships among involved actors. Combined with the convergence design perspective, this insight could imply operative management approaches, i.e. the short-term perspective, to facilitate the design (e.g. by supporting product development and time-to-market), whereas strategic management approaches, i.e. the long-term perspective, would be required in order to remain competitive due to continuous network-oriented business model redefinition. Hence, from a convergence perspective, it is crucial to understand how interorganizational networks have to be constructed, maintained and continuously reconfigured, in order to sustain competitive advantage and allow value creation.

4 Observed design practices in converging environments

4.1 Case: ICT industry

Convergence in ICT has in past years implied a paradigm shift for applications. We have seen personal computers decrease in size and increase in mobility, whereas in parallel mobile telephones have evolved towards rich terminal devices, both hence converging into multiradio access mobile computing stations, allowing a wide range of new application areas (figure 2). Nevertheless, evolving market and technology trends, derived from the convergence development, increasingly expose mobile operators (MOs) into an emerging dilemma. Analyzing the strategic positioning within in the ICT landscape, the competitive advantage can be observed as consisting of the value proposition of offering a bundle of both data carriage and value added services (VAS). Whereas high margins are generated by the VAS, the critical resource controlled by the operator however still is the data carriage infrastructure itself, being part of the altogether margin-intensive service bundle. Based on this consideration, the sustainability of the MOs’ competitive advantage is endangered, as new entrants will push MO-independent services into the market.

The adoption of Internet standards in telecommunication systems has been one of the most visible facets of convergence. Especially the adoption of the Internet protocol (IP) as the main network-level communication standard even in the wireless and mobile context, is a trend which in a longer term might change the competitive environment drastically. Major mobile device vendors have announced to rollout first voice-over-IP-based (VoIP) handsets throughout this year, pushing the session initiation protocol (SIP) as the new open standard, paving the way for the final shift of voice telephony towards packet-switched data transmission. As a consequence, once the entire content transmitted by MOs is implemented as packet-based data transmission, with no technical differentiation between voice and data anymore, MOs will sooner or later have to modify their back-end infrastructure towards a full IP-based core. This migration will on the one hand assure MOs’ future compatibilities with Internet systems and thereby enable them to implement the full range of service offering opportunities for their customers. On the other hand however, this will cause an unbundling of data and services for MOs, forcing them to respectively reposition themselves into two separate competitive environments. In the role of a data carriage provider, they will compete on bandwidth, speed, price and quality of services, whereas as a service provider, the MOs will compete with any provider of similar services connected to the Internet. This will render difficulties in value creation according to the old manner: the same approach of benefiting from a strong customer base in the data carriage segment in combination with margin-intensive services will no longer be possible. MOs risk losing control of VAS differentiation, as the customers might choose to use the operator for data transmission only, purchasing the services elsewhere within the value generating network provided by the Internet. This might sooner or later transform the MOs to 'bit pipes' only.

From the end-user's perspective, this paradigm shift can be illustrated by the inverted functionality of Internet and phone-based services. Whereas in the 1990ies, phone lines were used for accessing the Internet, i.e. applying IP on top of phone carrier lines, the application of today is vice versa: phone calls are being routed over the internet, using VoIP technologies for placing phone calls on top of IP.

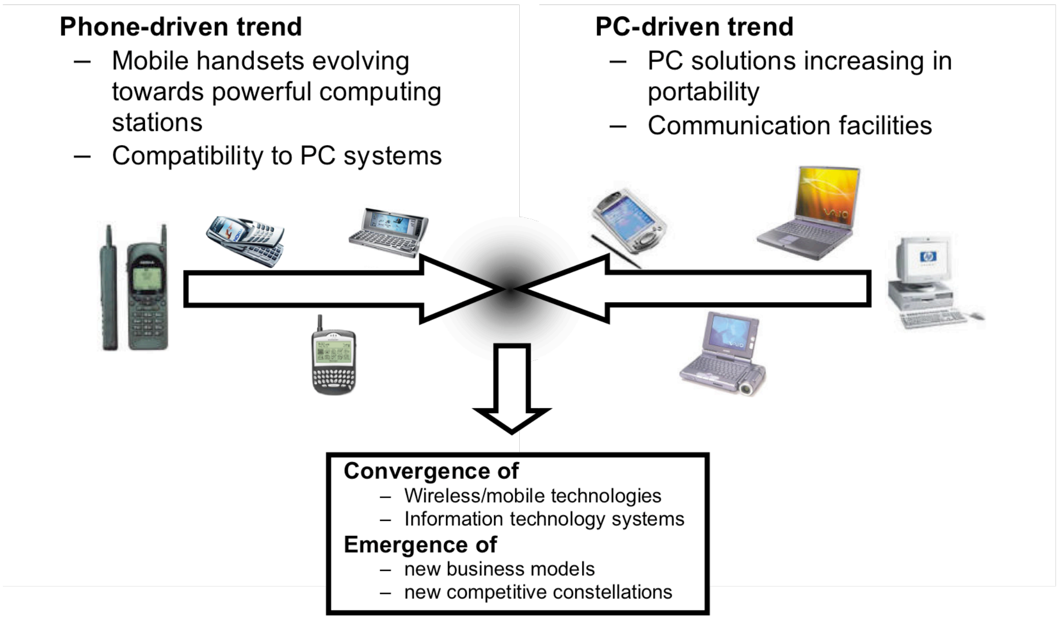

Figure 2. Convergence of two disparate technology trends into one business segment

4.1.1 A service provisioning perspective

Within a qualitative case study, the intersection between two firms in the ICT sector has been observed through press survey, interviews with technology management representatives, as well as through discussions within related research project collaborations.

Company A is a telecommunications equipment and infrastructure manufacturer, holding a major stake in its respective market, distinguishing itself through technology rather than services. Company B is a small and medium sized enterprise (SME), can be regarded as one step closer to the customer within the value chain, developing provisioning solutions for a specific service type.

Company A is currently undergoing a slight strategic reorientation towards more service provisioning-oriented business activities, and has been trying to offer solutions within the same service segment as covered by B during several years. Hence, A and B have until recently been regarded as competing within the same market, despite the different magnitudes and underlying business models of the firms. Company B has actively been establishing contacts to firm A, as it was knowledgeable about A desperately trying to develop a proprietary standard with minor success. Based on this networking, B was well positioned as A recently launched an aggressive partnering strategy, deciding to address the customer demand in this service segment through collaboration with eight SMEs. Since the service segment is fragmented into many sub-niches, all of which referring to specific customer demands, company A was with the help of B able to offer a broader solution portfolio through managing partners instead of the technologies, thereby avoiding to integrate or internally build all required competencies. In other words, the small player B was at the right place when A made a commitment on actively participating in a value network. This can be explained by the strategic focus of company B, committing onto partnership management as a key source for competitive advantage, constantly re-assessing and reconfiguring the value network, instead of leaving it on a static basis. Interestingly, company A gave up the plan to develop a *de facto* standard in-house for this service, a plan that originally was envisioning to gain a dominant design based on the existing market share, which further could have shaken out all small solution providers from the market. Instead, A decided to become world-market-leader by offering as many different solutions as possible. This decision was partly motivated by the trend of customer demands becoming increasingly specific and complex, requiring rather tailor-made, end-to-end solutions, than standard platforms. Based on this partnering strategy, both A and B were not only able to develop industry foresight in terms of understanding future market needs in more detail, but also to actively co-develop disruptive solutions through intersection.

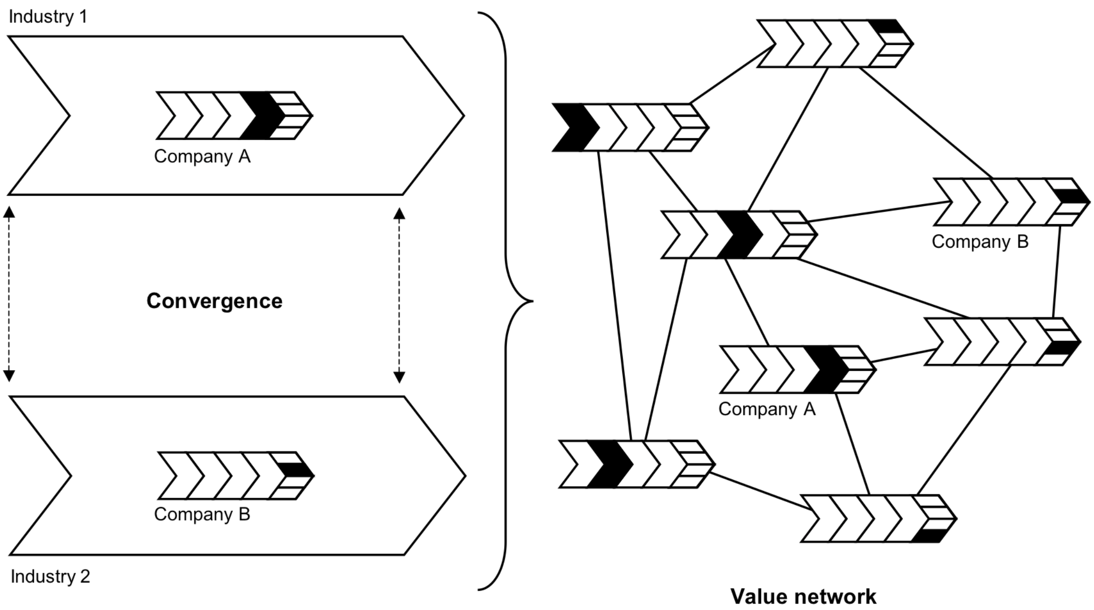

Figure 3. Horizontal and vertical integration in converging environments

4.1.2 Findings: Design processes in value networks

From the perspective of company B, the case turned out to be a rewarding way of opening-up the own design process into a value network, preventing the rather newly-established, small firm from market shakeout initiated by incumbents. Whereas the emerging technological convergence between underlying information and telecommunication services challenged the current value proposition of company B – a firm based on a business model constructed around the specific service – there was a clear long-term risk of e.g. company A being able to take-over the technology built by B. Through the collaboration between A and B, the small firm B can find itself positioned with its entire business model as an integral part within the value network of firm A.

The networked design approach created a win-win situation for both companies, allowing co-creation of value in a converging environment, through access to a broad variety of industry actors on the one hand, and the access to a wide portfolio of customer demand on the other hand. Based on the elaborations in the previous section, figure 3 attempts to depict an example for a value network, fostering disruptive design and innovation activities based on horizontal and vertical integration.

4.2 Case: Mechatronics

Companies that traditionally have been developing mainly mechanical products are more and more adding and integrating electronics and software systems into their products, thereby creating mechatronic systems. One industry for which this is highly relevant is the automobile industry [11] as the relative value of electronics in an automotive steadily increases, but many other industries (e.g. robotics and medical equipment) are also influenced.

About 80-90% of new functions in an automobile are electronics based [51, 69] and it is expected that a third of the total cost for a car will be carried by electronics in 2009 [30]. Technologies such as mechanics, electronics, and software are however more and more integrated in order to realize new functions not seen before and for more efficient use of resources, in other terms – mechatronic systems are deployed.

With mechatronic systems new opportunities for innovative technical solutions arise. For example, Electronic Stability Control (ESC) is a mechatronic system designed to electronically detect and assist the driver in critical driving situations. It relies on information from several sensors (e.g. wheel speed, steering wheel, yaw rate) and utilizes actuators (e.g. engine, drive train, brakes), computer networks, and electrical control units distributed on different technical sub-systems and technologies. The system compares a driver's intended course with the vehicle's actual movement. When instability is detected, ESC may automatically apply brakes to individual wheels and can also reduce engine torque to help keep the driver on track.

A qualitative and inductive approach was chosen for this case study. The whole study was conducted over six months, and empirical data were collected through observations and interviews. All interviews were tape-recorded and transcribed. The observations were undertaken three days a week over ten weeks. Records were taken of 31 formal meetings and numerous informal talks during coffee breaks and hallway meetings. A protocol served as a template for collecting data during the formal meetings, and data from informal meetings were summarized in daily notes.

The product development organization in this case study was part of a European premium brand automotive company. This company is an integral part of a global automotive group that involves several companies in different segments and different countries. The present study was delimited by a project and a mechatronical system that were part of a global product platform development project. Core issues in this project were the integration of heterogeneous subsystems into overarching mechatronical systems and the realization of distributed functionalities.

The purpose of this case study was to explore integration in a mechatronical development setting, and especially how work procedures and competence management was affected by multidisciplinary product development.

4.2.1 Findings: Mastering complexity in design

The development of mechatronics entails integration at the organizational level as well as the team level. This case study showed that high complexity in both the product and the organization meant that considerable effort had to be expended to coordinate design activities and support the development of a common perspective on what was to be done.

The formal structure of the organization reflected a traditional approach consistent with the architecture of the mechanical product. The main entities of the organization were divided in accordance with the physical subsystems of an automobile. This organizational structure was reported to be less than supportive for integration when developing mechatronical systems that spanned several subsystems and organizational units. Engineers working with systems formerly considered stand-alone had to seek new means for mastering their complex job. To the engineers, the main advantage of reducing the perceived distance between disciplines was the possibility of influencing co-workers' decision-making related to their own work and problem solving, thereby developing optimised and integrated mechatronical systems.

One major challenge was found in the coordination and integration of design activities. It was critical for the design engineers to separate specific information out from the massive information flow. Coordination activities were primarily concerned with the technical interfaces of the subsystems and technologies. Integration activities were primarily concerned with teamwork and collaboration within and between design teams. According to the interviewees, there were no obvious or well-understood organizational roles, work procedures, or computer tools that fully supported the coordination and integration of technical interfaces, at least none that involved the design teams.

5 Discussion

For the management of design practices in converging environments, it is vital but complicated to be able to look beyond disciplinary needs and work towards an optimized design of a multidisciplinary technical system. For example, it may be strategically right to replace an expensive and precise mechanical system by a synergistic combination of a cheaper but highly advanced control system and a less precise mechanical system to get an increased performance of the system as well as a decreased cost. Such a decision may be hard to accept for mechanical engineers, as they have to give up their power of critical design knowledge.

The importance of support from management for successful mechatronics engineering cannot be overlooked. The managerial objective is to set the scene and support synergistic design activities. It is described in Adamsson [4] that product development managers with a mechanical engineering background sometimes tend to underestimate the complexity that mechatronics and software engineering give rise to. A product development approach may remain unchanged if managers lack knowledge about implications given by a mechatronic product strategy. It is crucial to change from a traditional disciplinary view to a synergistic and multidisciplinary view as the earned value of mechatronics is related to synergistic technical integration.

Identification of the relation between the product architecture and the organizational structure is one activity where involvement of both representatives from management and effected engineering disciplines should be promoted. The relationship between an organizational design and product architecture is critical but intricate for mechatronic products. For products that involve technologies with different abstraction levels (for example a mechatronic product), declaring interfaces and assigning responsibilities to organizational functions and role-differentiated engineers is a complicated process. Complex relations and critical dependencies arise on many levels, both in the product and the organization, as a consequence of the differentiated abstraction levels for components, functions, and sub-systems.

As reported in Adamsson [3], software competence was allocated to the electrical engineering departments in the early stages of implementing a mechatronics design approach. It is a result of the traditionally tight coupling between electronics and software, and it is therefore more natural to cluster a minority of software engineers with the electrical engineers rather than with the mechanical engineers. But as the relative value of software in the product and the number of software engineers increases, one should reassess how the mixture of disciplines should be set to promote efficient teamwork.

In the ICT case, common strategic approaches can be observed in all terms of opening-up innovation activities in deconstructed value creation environments. In particular for large firms, the phenomenon of technological convergence represents an illustrative special case for the innovator's dilemma [20], consisting of the major general obstacle why great companies fail to innovate, i.e. the "inability to escape the past" and the "inability to create the future" [39]. Furthermore, it is argued that static value networks alone do not secure sustainable competitive advantage in converging environments, as "a business inside a value network will have a much tougher time pursuing an intersectional idea than one that has managed to remain outside of it" [44]. However, the continuous reconfiguration of value networks can allow actors in converging environments to on the one hand maintain foresight on external tendencies and potential areas of disruption, and on the other hand actively develop intersections.

Table 1. Critical issues for managing design practices in converging environments

Strategic issues	*Operative issues*
- Observation of technology trends and emerging industry changes - Allocating industry foresight resources for identifying opportunities for intersectional innovation - Continuous reassessment of technology portfolio and roadmap - Continuous reassessment of competencies portfolio and roadmap - Continuous reassessment of value network and partnership roadmap	- Organizing for interdisciplinary collaboration - Management commitment for setting the scene and supporting synergistic design activities - Knowledge management (KM) - Communication of product strategy - Relation between product architecture and organizational structure - Appropriate mixture of disciplines in teambuilding

6 Conclusions

An overview of critical issues for the management of design practices in converging environments, providing a conceptual basis for deriving management models is compiled in table 1. In summary, the convergence of technologies implies convergence and integration of design practices and even convergence and integration of entire industries in the long-term. Hence, the alignment and management of competencies and alliances is important in such a context both in short-term (i.e., operative) as well as in long-term (i.e., strategic) perspective. Furthermore, it can be stated that technical and knowledge oriented interfaces are not the only challenge for intersectional innovation: design culture differs drastically among different skill areas and industries, rendering it a crucial factor for the successful implementation of design projects. As far as the integration perspective is concerned, horizontal integration implies the bundling of products and functionalities provided by underlying systems, whereas vertical integration implies the inclusion of subsystems into systems. Finally, there is a current lack of knowledge on the “big picture” of technological convergence, where a better understanding could help to resolve many challenges in design.

7 References

[1] Abernathy, W. J. and Clark, K. B., "Innovation - Mapping the Winds of Creative Destruction," *Research Policy*, vol. 14, pp. 3-22, 1985.

[2] Achrol, R. S. and Kotler, P., "Marketing in the network economy," *Journal of Marketing*, vol. 63, pp. 146-163, 1999.

[3] Adamsson, N., "Modellbaserad mekatronikutveckling och kompetensintegration: en komparativ fallstudie inom svensk fordonsindustri," KTH Maskinkonstruktion, Kungliga Tekniska Högskolan, Stockholm, 2003.

[4] Adamsson, N., "Mechatronics engineering - New requirements on cross-functional integration", KTH Machine Design, Licentiate thesis. Stockholm: The Royal Institute of Technology, 2005.

[5] Afuah, A., "Dynamic boundaries of the firm: Are firms better off being vertically integrated in the face of a technological change?" *Academy of Management Journal*, vol. 44, pp. 1211-1228, 2001.

[6] Afuah, A. and Tucci, C. L., "A model of the internet as creative destroyer," *IEEE Transactions on Engineering Management*, vol. 50, pp. 395-402, 2003.

[7] Amit, R. and Zott, C., "Value creation in e-business," *Strategic Management Journal*, vol. 22, pp. 493-520, 2001.

[8] Athreye, S. and Keeble, D., "Technological convergence, globalisation and ownership in the UK computer industry," *Technovation*, vol. 20, pp. 227-245, 2000.

[9] Backholm, A. and Hacklin, F., "Estimating the 3G convergence effect on the future role of application-layer mobile middleware solutions: scenarios and strategies for business application providers in 3G and beyond," in: Proceedings of the 2002 International Conference on Third Generation Wireless and Beyond (3Gwireless'02), San Francisco/Silicon Valley, CA, USA, 2002.

[10] Bannister, J., Mather, P., and Coope, S., *Convergence technologies for 3G networks IP, UMTS, EGPRS and ATM*. Chichester: Wiley, 2004.

[11] Barron, M. B. and Powers, W. F., "The role of electronic controls for future automotive mechatronic," *IEEE/ASME Transactions on Mechatronics*, vol. 1, pp. 80-88, 1996.

[12] Betz, F., *Strategic Technology Management*. New York: McGraw-Hill, 1993.

[13] Birkinshaw, J., "Managing internal R&D networks in global firms - What sort of knowledge is involved?" *Long Range Planning*, vol. 35, pp. 245-267, 2002.

[14] Bohlin, E., Brodin, K., Lundgren, A., and Thorngren, B., *Convergence in Communications and Beyond*: North-Holland, 2000.

[15] Born, G., "Strategy, positioning and projection in digital television: Channel Four and the commercialization of public service broadcasting in the UK," *Media Culture & Society*, vol. 25, pp. 773-+, 2003.

[16] Borés, C., Saurina, C., and Torres, R., "Technological convergence: a strategic perspective," *Technovation*, vol. 23, pp. 1-13, 2003.

[17] Carlsson, M., "Aspects of the integration of technical functions for efficient product development," *R&D Management*, vol. 21, pp. 55-66, 1991.

[18] Charan, R., "How Networks Reshape Organizations - for Results," *Harvard Business Review*, vol. 69, pp. 104-115, 1991.

[19] Chesbrough, H. W. and Teece, D. J., "Organizing for innovation: When is virtual virtuous?" *Harvard Business Review*, vol. 80, pp. 127-+, 2002.

[20] Christensen, C. M., *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston: Harvard Business School Press, 1997.

[21] Daniel, H. Z., Hempel, D. J., and Srinivasan, N., "A model of value assessment in collaborative R&D programs," *Industrial Marketing Management*, vol. 31, pp. 653-664, 2002.

[22] Duysters, G., Hagedoorn, J., and Maastricht Economic Research Institute on Innovation and Technology, *Technological convergence in the IT industry: the role of strategic technology alliances and technological competencies*. Maastricht: Maastricht Economic Research Institute on Innovation and Technology, 1997.

[23] Edwards, J., "Convergence reshapes the networking Industry," *Computer*, vol. 32, pp. 14-16, 1999.

[24] Eisenhardt, K. M. and Martin, J. A., "Dynamic capabilities: What are they?" *Strategic Management Journal*, vol. 21, pp. 1105-1121, 2000.

[25] Engwall, M., Forslin, J., Kaulio, M., Norell, M., and Ritzén, S., "Engineering management for integration," in: Proceedings of the 14th International Conference on Engineering Design (ICED'03), Stockholm, Sweden, 2003.
[26] Fransman, M., "Mapping the evolving telecoms industry: the uses and shortcomings of the layer model," *Telecommunications Policy*, vol. 26, pp. 473-483, 2002.
[27] Freeman, C. and Louçã, F., *As Time Goes By. From the Industrial Revolution to the Information Revolution.* Oxford: Oxford University Press, 2001.
[28] Gartner Group, "Technology convergence driving business model collision," Teleconference presentation, 25 March 2003.
[29] Gassmann, O. and von Zedtwitz, M., "Trends and determinants of managing virtual R&D teams," *R & D Management*, vol. 33, pp. 243-262, 2003.
[30] George, R. and Wang, J., "Vehicle E/E System Integrity from Concept to Customer," in *SAE Convergence 2002*. Detroit, MI: SAE 2002-21-0018, 2002.
[31] Gomes, J. F. S., de Weerd-Nederhof, P. C., Pearson, A. W., and Cunha, M. P., "Is more always better? An exploration of the differential effects of functional integration on performance in new product development," *Technovation*, vol. 23, pp. 185-191, 2003.
[32] Goyal, S. and Moraga-Gonzalez, J. L., "R&D networks," *Rand Journal of Economics*, vol. 32, pp. 686-707, 2001.
[33] Greenstein, S. M. and Kanna, T., "What does industry convergence mean?" in *Competing the age of digital convergence*, Yoffie, D. B., Ed. Boston/MA: Harvard Business School Press, 1997, pp. 201-226.
[34] Greenstein, S. M., "Technological convergence," in *Technology Management Handbook*, Dorf, R. C., Ed.: CRC Press LLC, 2000.
[35] Götte, S., *Konvergenz der TIME-Märkte: empiriegestützte Entwicklung eines adaptiven und innovativen Konzeptrahmens für ein kooperatives und integrierendes, geschäftskundenbezogenes Marketingmanagement Schweizer Anbieter*. München: Rainer Hampp Verlag, 2003.
[36] Hacklin, F. and Marxt, C., "Assessing R&D management strategies for wireless applications in a converging environment," in: Proceedings of the R&D Management Conference 2003 (RADMA), Manchester, England, 2003.
[37] Hacklin, F., Marxt, C., and Fahrni, F., "Technology partner selection for collaborative innovation in production systems: a decision support system based approach.," in: 13th International Working Seminar on Production Economics, Igls/Innsbruck, Austria, 2004.
[38] Hacklin, F., Raurich, V., and Marxt, C., "How incremental innovation becomes disruptive: the case of technology convergence," in: Proceedings of the IEEE International Engineering Management Conference, Singapore, 2004.
[39] Hamel, G. and Prahalad, C. K., *Competing for the future*. Boston: Harvard Business School Press, 1994.
[40] Harashima, F., Tomizuka, M., and Fukuda, T., "Mechatronics-"What is it, why, what?" An editorial," *Mechatronics, IEEE/ASME Transactions on*, vol. 1, 1996.
[41] Hinterhuber, H. H. and Levin, B. M., "Strategic Networks - the Organization of the Future," *Long Range Planning*, vol. 27, pp. 43-53, 1994.
[42] Ireland, R. D., Hitt, M. A., and Sirmon, D. G., "A model of strategic entrepreneurship: The construct and its dimensions," *Journal of Management*, vol. 29, pp. 963-989, 2003.
[43] Jassawalla, A. R. and Sashittal, H. C., "Accelerating technology transfer: thinking about organizational pronoia," *Journal of Engineering and Technology Management*, vol. 15, pp. 153, 1998.
[44] Johansson, F., *The Medici Effect: Breakthrough Insights at the Intersection of Ideas, Concepts, and Cultures*. Boston: Harvard Business School Press, 2004.
[45] Jones, G. K., Lanctot, A., and Teegen, H. J., "Determinants and performance impacts of external technology acquisition," *Journal of Business Venturing*, vol. 16, pp. 255-283, 2001.
[46] Kahn, K. B. and Mentzer, J. T., "Marketing's integration with other departments," *Journal Of Business Research*, vol. 42, pp. 53-62, 1998.
[47] Kahn, K. B., "Market orientation, interdepartmental integration, and product development performance," *Journal Of Product Innovation Management*, vol. 18, pp. 314-323, 2001.
[48] Karlsson, M., *The liberalisation of telecommunications in Sweden: technology and regime change from the 1960s to 1993*. Linköping: Tema Univ., 1998.
[49] Lambe, C. J. and Spekman, R. E., "Alliances, external technology acquisition, and discontinuous technological change," *Journal of Product Innovation Management*, vol. 14, pp. 102-116, 1997.
[50] Lee, G. K.-F., "The Competitive Consequences of Technological Convergence in an Era of Innovations - Telephony Communications and Computer Networking, 1989-2001", PhD thesis. Berkeley: Haas School of Business, University of California, 2003.
[51] Leen, G. and Heffernan, D., "Expanding automotive systems," *IEEE Computer*, vol. 35, pp. 88-93, 2002.
[52] Lei, D. T., "Industry evolution and competence development: the imperatives of technological convergence," *International Journal of Technology Management*, vol. 19, pp. 699-738, 2000.

[53] Li, F. and Whalley, J., "Deconstruction of the telecommunications industry: from value chains to value networks," *Telecommunications Policy*, vol. 26, pp. 451-472, 2002.
[54] Miller, J. P., "Creating value in the network economy," *Journal of Academic Librarianship*, vol. 25, pp. 493-494, 1999.
[55] Miotti, L. and Sachwald, F., "Co-operative R&D: why and with whom? An integrated framework of analysis," *Research Policy*, vol. 32, pp. 1481-1499, 2003.
[56] Moenaert, R. K., Souder, W. E., Demeyer, A., and Deschoolmeester, D., "R-And-D-Marketing Integration Mechanisms, Communication Flows, And Innovation Success," *Journal Of Product Innovation Management*, vol. 11, pp. 31-45, 1994.
[57] Nikolaou, N. A., Vaxevanakis, K. G., Maniatis, S. I., Venieris, I. S., and Zervos, N. A., "Wireless convergence architecture: A case study using GSM and wireless LAN," *Mobile Networks & Applications*, vol. 7, pp. 259-267, 2002.
[58] Olla, P. and Patel, N. V., "A value chain model for mobile data service providers," *Telecommunications Policy*, vol. 26, pp. 551-571, 2002.
[59] Pavitt, K., "Systems integrators as "post-industrial" firms?" in: DRUID Summer Conference on Industrial Dynamics of the New and Old Economy, Copenhagen, Denmark, 2002.
[60] Picot, A., Reichwald, R., and Wigand, R. T., *Die grenzenlose Unternehmung Information, Organisation und Management*, 5., aktualisierte Aufl. ed. Wiesbaden: Gabler, 2003.
[61] Pringle, D., "Clash of the titans," in *The Wall Street Journal Europe*, 2003, pp. R1-R2.
[62] Rockenhäuser, J., *Digitale Konvergenz und Kompetenzenmanagement*. Wiesbaden: Deutscher Univ.-Verlag, 1999.
[63] Rosenberg, N., "Technological-Change in the Machine-Tool Industry, 1840-1910," *Journal of Economic History*, vol. 23, pp. 414-443, 1963.
[64] Rosenberg, N., "Uncertainty and technological change," in *The Mosaic of Economic Growth*, Landau, R., Taylor, T., and Wright, G., Eds. Stanford, CA: Stanford University Press, 1996.
[65] Sabat, H. K., "The evolving mobile wireless value chain and market structure," *Telecommunications Policy*, vol. 26, pp. 505-535, 2002.
[66] Sherif, M. H., "Convergence: A new perspective for standards," *Ieee Communications Magazine*, vol. 36, pp. 110-111, 1998.
[67] Steinbock, D., "Assessing Finland's Wireless Valley: can the pioneering continue?" *Telecommunications Policy*, vol. 25, pp. 71-100, 2001.
[68] Steinbock, D., "Globalization of wireless value system: from geographic to strategic advantages," *Telecommunications Policy*, vol. 27, pp. 207-235, 2003.
[69] Steiner, P. and Schmidt, F., "Anforderungen und Architektur zukünftiger Karosserieelektronik-systeme," in *Proceedings for 10 Internationaler Kongress Elektronik im Kraftfahrzeug*. Kongresshaus Baden-Baden, 2001.
[70] Teece, D. J., Pisano, G., and Shuen, A., "Dynamic capabilities and strategic management," *Strategic Management Journal*, vol. 18, pp. 509-533, 1997.
[71] Weber, B., *Die Fluide Organisation konzeptionelle Ueberlegungen für die Gestaltung und das Management von Unternehmen in hochdynamischen Umfeldern*. Bern [etc.]: Paul Haupt, 1996.
[72] Wen, J. and Kobayashi, S., "Exploring collaborative R&D network: some new evidence in Japan," *Research Policy*, vol. 30, pp. 1309-1319, 2001.
[73] Wiley, D. L., "Creating value in the network economy," *Econtent*, vol. 22, pp. 94-94, 1999.
[74] Yoffie, D. B., *Competing the age of digital convergence*. Boston/MA: Harvard Business School Press, 1997.

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