A process theory of competency rallying in engineering projects[1]

Bernhard R. Katzy[2]

Universität der Bundeswehr München
Fakultät für Luft- und Raumfahrttechnik
Institut für Industrielle Informationsprozesse

Werner-Heisenberg-Weg 39
D-85579 Neubiberg
Germany

Telephone: +31 (65) 1125–432
Fax: +31 (65) 1125–927
Email: bernhard.katzy@unibw-muenchen.de

Kevin Crowston

Syracuse University
School of Information Studies

4–206 Centre for Science and Technology
Syracuse, NY 13244–4100
USA

Telephone: +1 (315) 443–1676
Fax: +1 (315) 443–5806
Email: crowston@syr.edu

Draft of 6 April, 2001

Please do not cite or distribute.

---

[1] The Virtual Factory project was started by the Institute for Technology Management, University of St. Gallen, which is. headed by Professor Günter Schuh. Financial support was provided by The Swiss Commission for Scientific Research (KwF) and the Virtual Factory partner companies. The Virtual Factory project team included Bernhard Katzy, Kai Millarg, Thomas Zehnder, Stefan Eisen and Åsa Göransson, as well as managers from the partner firms. The authors thank all of the participants in the Virtual Factory project for their contributions and in particular, for the many discussions that led to the concepts discussed in this paper. The authors take sole responsibility for the work presented here. This paper has benefited greatly from discussion with Paul van Fenema, Steven Sawyer, Ping Zhang and Robert Heckman, Barbara Kwasnik and Gisela von Dran.

[2] Please address all correspondence to the first author.

A process theory of competency rallying in engineering projects

Abstract (142 words)

Firms face an environment changing at an increasingly rapid pace. Market opportunities in particular can arise and disappear in a short time. Unfortunately, the speed with which organizations can adapt their strategies and competencies to meet these opportunities remains limited. We argue that firms can address these individual limitations by cooperating with others for access to market opportunities and needed competencies. In this paper, we present a process theory of how a network of firms can reliably engineering and deliver products in the face of rapid market changes. In this theory, the success of the network is predicated on 1) identification and development of competencies, 2) identification and facing of market opportunities, 3) marshalling of competencies and 4) a short-term cooperative effort. Our theory is based on the experiences of Virtual Factory, an organized network for regional cooperation in the manufacturing industry.

Competency rallying

Index terms

Virtual organization

Virtual Factory project

Virtual Factory project

Core competencies

Resource-based view of the firm

Competency rallying

Market-facing

Dynamic capabilities?

Concurrent engineering?

A process theory of competency rallying in engineering projects

Firms face an environment changing at an increasingly rapid pace. Market opportunities in particular can arise and disappear again in a short time. However, the speed with which organizations can adapt to changes remains limited. We refer to this situation, where the environment changes more rapidly than organizations can adapt, as a “turbulent environment”. Turbulent environments re-pose two central questions addressed by theories of the firm: How does the firm behave in its market? and How is work organized?

In stable environments, the answers provided to these questions distinguish two broad types of theories of the firm. In the first type of theory—an outside-in perspective—markets are assumed to determine the organization of work. This perspective is described in the structure-conduct-performance principle [1] of the industrial organization school, which contends that the existing industry structure calls for the adapted conduct of firms to achieve the most competitive performance. It is the role of management to craft deliberate strategies to translate industry realities into appropriate organizational structures. In short, ‘structure follows strategy’ [2].

In the second type of theory—an inside-out perspective—existing structures explain a firm’s market behavior. This perspective is conveyed by the resource-based view of the firm [3]. While scholars refer to the resource-based view of the firm [3] in business writing, the term “core competency” is in common use [4]. In any case, if these competencies are valuable, rare, inimitable, and embedded in the organization, they define a resource barrier and consequently, are a source of sustainable competitive advantage. In other words, strategies are perceived to emerge from the organizational structure and culture as long-term pattern of organizational behaviour [5].

While both types of theories deliver fruitful alternative explanations of the nature of a firm in stable environments, the two questions point to opposite ends of a paradox for firms in turbulent environments. On the one hand, the insight of the first type of theory—that deliberate strategy is necessary —remains true in the face of short-term market opportunities. However, in a turbulent environment, as we have defined it, time constraints make it impossible for firms to adopt appropriate organizational structures and routines to ensure performance for each change in the market.

On the other hand, the insight from the second type of theory—that competencies inside the firm are a source of competitive advantage—holds true especially for short-term market opportunities. The more valuable a competency is, the longer it takes to develop (often a decade or more [4]), so other firms can not readily develop competing competencies to meet short-term opportunities. However, the unpredictable nature of market opportunities in turbulent environments increases the risk that necessary competencies may be missing and that existing competencies may become irrelevant or outdated. In short, turbulent environments make appropriate strategy and competencies simultaneously more important yet seemingly less attainable.

In this paper, we follow the suggestion of Poole and van der Ven [6] to resolve this paradox by recognizing these theoretical insights as distinct phases in a process that unfolds over time and across a network of cooperating firms. In the remainder of this introduction, we describe how a network of firms can overcome the limitations identified above, before turning to a presentation of our research approach and theory-building efforts.

Virtual organizations for competency rallying

We argue that one way for firms in turbulent environments to address their individual limitations is to cooperate with others for access to market-opportunities and needed competencies. We use the term “rallying”, meaning, “to rapidly reunite for concentrated effort” [7], to describe *the process of developing and bringing together in temporary cooperation a network of firms with the competencies needed to satisfy a newly-identified market opportunity.* The identification of competencies in the first phase of the process is thus complemented in later phases by the identification of possible new markets and by the quick recombination and connection of competencies held by different members of the network, resolving the paradox described above.

While the potential value of such cooperation is becoming more widely accepted, the details of competency rallying are little understood. The contribution of this paper is to develop a process theory of competency rallying grounded in an action research study of one successful virtual organization, the Virtual Factory (the “Virtuelle Fabrik” in the original German). The basic building blocks of our process theory have been discussed before, of course. For example, the role played by market recognition and competency recombination is evident in the Prato region of Italy [8-10], in which many small textile manufacturing firms specialize in various aspects of textile and apparel production, such as weaving, dying, sewing, etc. These small companies are not able to identify worldwide customers, nor do they offer a complete range of desired services. Instead merchants, impannatores, provide access to the highly volatile fashion market opportunities for the entire industrial district [8] and temporarily bring together numerous small companies to fill the requirements for each particular contract. Similarly, Prahalad [4] notes that to develop competencies, they must be used and re-used in many different markets and contexts. However, our theory is novel in the way that it weaves together an external perspective on market-facing with an internal perspective on competency development and marshalling to describe the overall process of competency rallying.

Following Weick's [11] approach to theory building, we develop a relatively full explanation of competency rallying in a small region, which is then used to guide a general discussion of rallying in other settings. In the following section, we describe the particular research setting, overall methodology and data collection. In the subsequent section, we describe each phase of our proposed theory in turn. We conclude by discussing factors important in the success of the Virtual Factory and lessons for further research using the proposed theory.

Methodology

In this section, we describe the setting for our research project, the research approach and the sources of data used.

Research setting: The Virtuelle Fabrik

Our study was conducted at the "Virtuelle Fabrik in Euregio Bodensee" (that is, the Virtual Factory in the Lake Bodensee region of Germany, Switzerland and Austria), an organized network for regional cooperation in the manufacturing industry. The Virtual Factory routinely engineers and manufactures new products by recombining the competencies of its members to meet short-term market opportunities. Members of this network have cooperatively produced dozens of products and services, ranging from machining simple parts to a complex module for a letter-sorting machine. Table 1 presents several examples of projects worked on by the Virtual Factory and a brief description of the way competencies from the network were rallied for these projects.

Insert Table 1 about here

Project leadership (the core partners) comprised entrepreneurs and senior managers from companies in the region and four researchers from the Institute for Technology

Management of the University of St. Gallen in Switzerland (including one of the authors as the project leader). The researchers wanted to study new forms of organization in industry, in particular, the role of virtual organizations in meeting the challenges raised by the changing role of information technology and globalization of industries. Analysis before the start of the project led the researchers to believe that existing theories only partly addressed the managerial issues raised by these changes. Furthermore, they concluded that descriptive research designs would be insufficient to bring to light the possibilities raised by these changes. Instead, the project would need to develop and experiment on its own organizational test bed.

Research approach: Collaborative action research

The research project was carried out as a four-year collaborative action research project [12-14]. Action research is an interventionist approach to the development of scientific knowledge (in contrast to more typical observational or survey approaches). To understand the process of cooperation between the project organizations, the core partners assumed the role of active promoters. Researchers acted partly as change agents in the firms and partly as observers of the change processes, “alternating the change agent and researcher roles” [15, p. 420, citing [16]]. To implement change, organizational development activities took place in all participating companies and involved members at all organizational levels.

Action research was an appropriate methodology for this study because at the time it started, the type of cooperation envisioned was not common. Indeed, at the time it would have been difficult to identify even one real-world example of a virtual organization in high-precision engineering and manufacturing, much less survey hundreds of examples. Therefore, in order to study the process of cooperation in these organizations, the researchers had to be involved in establishing the preconditions for it. More importantly, the researchers had only a general idea of how cooperation could be established, so the active participation of practitioners from the member companies was necessary for the success of the project.

Susman and Evered [13] describe a five-phase cyclic process for action research, consisting of 1) diagnosing, 2) action planning, 3) action taking, 4) evaluating and 5) specifying learning. *Diagnosing* includes identification of the primary problems that underlie the organization’s desire to change and leads to the development of working hypotheses about the state of the organization. In this phase, action researchers can use techniques similar to organizational ethnography as a way to develop thick descriptions of the dynamics and processes of the organizations involved in the project.

In the next phase, *action planning*, researchers and practitioners collaborate in determining organizational activities to address the problems identified. This planning is based on the theories and models brought to bear by the researchers as well as the knowledge of the practitioners. In other words, the research may be both theory-driven and theory-building.

In the *action-taking* phase, the planned changes are implemented. Being part of the change process enables the researchers to be participant-observers in the processes being studied. After the actions are taken, researchers and practitioners collaborate in *evaluating* the outcomes. This evaluation includes determining whether the actions had the theoretically expected effects and if they were effective in relieving the problems, a form of theory testing.

In the final phase, *learnings* from the actions and results are formally specified. This phase distinguishes action research as a research method rather than simply a type of change effort. Baskerville and Wood-Harper [17] suggest three audiences for these learnings. Firstly, the participant organizations can be restructured to reflect the new knowledge gained in the interaction. Secondly, where the change was unsuccessful or only partly successful, the learnings may lead to a new round of diagnosis and action planning. Finally, the test or building of the theoretical framework in practice contributes to the development of scientific knowledge.

The Virtual Factory project had three nested action-research cycles. At the shortest time scale, innovations in specific projects were formally discussed at quarterly round-table assemblies of the researchers and partners in the project. At the next level, external workshops and conferences were organized roughly twice a year to present and discuss project accomplishments with a broad industry audience. In total, approximately 1000 upper-level managers from non-related companies attended these meetings. Finally, at the longest time-scale, the project underwent three major funding cycles during the four years. Each funding decision involved formal reviews of reports and proposals by a committee of industrial and scientific reviewers assigned by the Swiss funding body (KwF, the Commission for Scientific Research) and formal investment decisions from the project companies.

Data collection and analysis

There are significant similarities between action research and other kinds of qualitative research in the modes of data collection. The evidence guiding our descriptions of and inferences about the process of competency rallying is divided into eight general categories:

- **Semi-structured interviews with company managers.** The researchers conducted nearly 100 semi-structured interviews to diagnose a variety of topics with company managers. Interviewees included company directors, and managers and employees involved in in- and outsourcing at all levels and departments (e.g., production, finance, quality inspections, industrial engineering, purchasing, etc.). Each round of interviews lasted three to four days and resulted in a report describing the situation of the firm.

- **Questionnaires**. Questionnaires were frequently used to collect data as basis both for diagnosis of network activities (e.g., data about the business figures of the partner companies) and for the very specific planning (e.g., to collect descriptions of the resources available in the network), execution (e.g., to identify the expectations towards customers and /or suppliers in outsourcing relationships) and evaluation of action interventions (e.g., the number of proposals pending and number of orders executed in the network at certain points in time).

- **Project plans.** The project was co-funded by the participating companies and the Swiss Commission for Scientific Research (KwF). The project plans showed the results achieved in the prior year, lessons learned from this work and the specification of concrete actions for the year to come.

- **Project meetings with partners.** Regular meetings were held among the partners to plan and take actions. Smaller formal meetings were held for parallel development work. For example, the “rules of the game” and the profiles of the roles were designed in this way. Researchers attended many meetings as change agents or to follow the developments.

- **Results of interventions.** The action interventions produced both intended and unintended results. Some of these results even appeared in parts of the partner companies remote from the project interventions.

- **Observations of projects.** Partner companies executed numerous manufacturing projects, about fifteen of which were directly observed by the researchers. The researchers followed the interventions, progress and difficulties encountered in these manufacturing projects to feed the observation back to the partner companies as lessons learned.

- **Informal discussions.** The researchers had hundreds, if not thousands, of informal conversations with managers and employees of the participant companies, ranging from brief interactions to long discussions over group dinners (known among participants as the "virtual dinner"). Researchers talked with employees at all hierarchical levels from all participant companies.

- **Formal Reports.** The researchers and managers regularly wrote up project results, which were defined as sub-projects from teams and work-packages. In 1998 a book was published in German reporting the project results [18] in general, though not including the model presented in this paper.

Action research can also use the same data analysis techniques as other kinds of qualitative research, though these individual analyses are situated within the overall framework of the action research cycle. We used an iterative process to develop inferences about the process of competency rallying. Each cycle began with a diagnosis of the current state of the project Virtuelle Fabrik inspired by the data and literature. Then, to see if this diagnosis could be supported, we developed an action plan, which was cooperatively implemented by the researchers and managers. The results of the intervention were observed and evaluated to see if the predictions were supported. These evaluations led us to discover complementary perspectives and facets of the process of competency rallying. As the priorities of the project shifted, we modified or maintained each inference about the process. Informal discussions and formal reporting of the project led to specification of the learning and to the next round of action learning. Finally, we wrote up our inferences about the various aspects of the process, adding conceptual arguments, additional examples and citations to relevant literature. Table 2 summarizes the evidence from the project that grounds our process theory of competency rallying.

Insert Table 2 about here

A process theory of competency rallying

Based on our analysis of the data from the project, we suggest that competency rallying involved four related sets of organizational activities, specifically: 1) identification and development of distinctive competencies in network members, 2) identification and facing of short-term market opportunities, 3) marshalling competencies from network partners for a particular market opportunity and 4) a short-term cooperative effort. The theory is summarized in Figure 1. The first two phases are performed on an on-going basis within the relatively stable network of firms in the Virtual Factory. These phases draw on competencies and market opportunities from a variety of industries, as indicated symbolically by the grey boxes. The final two phases are performed dynamically for each individual project.

Insert Figure 1 about here

For example, consider the development of the electric retraction device for a steering wheel, a product engineered and built within the Virtual Factory. The manufacturing project started when one of the network members, Wiftech, was approached by a customer and asked if they could provide the part. Wiftech itself did not have the capacity to build the part, but offered instead to take the project to the network, an example of facing a market opportunity, which would have been impossible without the project. Wiftech benefited by satisfying an important customer, as well as from a small piece of the final production. Wiftech passed the project on to a project leader from another firm, with whom they were acquainted from various project meetings. The project leader evaluated ten different technologies from ten independent firms in the network for technological feasibility and for their cost in the effort to design the part, an example of marshalling competencies. While ten companies were involved in the search for a technical solution, only three were involved in designing and manufacturing the first prototypes. The joint work of these companies at this stage is an example of a short-term cooperative effort. Final production required different partners, as the order quantities did not fit the one-of-a-kind manufacturing philosophy of the prototype manufacturers. Unstated in this example, but clearly necessary, were the on-going processes for developing and maintaining the competencies necessary to design and manufacture such a part in the first place.

Process vs. variance theories

In the terms used by Mohr [19], our theory is a process theory rather than the more typical variance theory. Variance theories comprise constructs or variables and propositions or hypotheses linking them. Such theories predict the levels of dependent or outcome variables from the levels of independent or predictor variables, where the predictors are seen as necessary and sufficient for the outcomes. Rather than relating levels of variables, process theories explain how outcomes of interest develop through a sequence of events [19]. These precursors are necessary for the outcome, but not sufficient in themselves, and outcomes are therefore only partially predictable from knowledge of the process. Mohr gives the example of a process theory of catching malaria. “The necessary conditions are the malarial parasite, persons already harboring the parasite, and *Anopheles* mosquitoes”. It is the combination of these elements that may lead to another infection, not the value of any single factor. The order of the events is also clearly important: a mosquito must bite an infected person before biting an uninfected person, not the other way around. Finally, the outcome is not inevitable, but can instead be a matter of chance. Being bitten by a mosquito does not inevitably lead to malaria. Still, Mohr notes that the laws of chance are still laws, and that process theories describe regularity in a probabilistic sense. For example, a known percentage of mosquito bites may lead to infection.

Our process theory explains how projects are identified and delivered in turbulent environments. Facing short-term market opportunities and developing long-term competencies within the network are two necessary preconditions for the organizational processes of marshalling competencies for a short-term cooperative effort. The theory explains the success of projects in terms of joining and separation of the two necessary conditions, as the two processes of recombination and co-operative effort.

For the purposes of this paper, we present competency creation, market facing, competency marshalling and cooperative effort as linear and distinct phases of the process. We present the theory in this way because it fits our data reasonably well and provides a simple and analytically useful way of presenting our theory. It should be understood that the process was usually not as clear and simple as the theory might imply. Phases could not always be clearly distinguished for particular manufacturing projects. In particular, as you move backward in the process, the time scale of the phases increases and their scope expands from a particular manufacturing project to the overall operation of the network.

Phase 1: Identification and development of competencies

The network rallies competencies provided by independent partner firms in the network. These firms can provide competencies from their various industries (as indicated symbolically by the grey boxes in Figure 1) that are potentially valuable yet not exploited in other industries. This view corresponds with the stream of literature on the resource-based view of the firm, which describes firms as collections of resources that can be deployed to establish competitive positions in multiple markets with heterogeneous products [20-22]. Even though the resource-based view is a theory of the firm, singular, it proved adaptable to the identification of resources from the network of firms involved in the Virtual Factory.

Through the course of the project, the conception of resources in the Virtual Factory gradually evolved and expanded. Initially, the view was quite limited: the original goal of the project was to increase machine utilization, so resources were machines. Descriptions of these machines across the industries were based on the generally accepted classification scheme and terminology from the DIN 8580 standard, which defines all possible machining operations.

Defining resources makes direct comparison across business or industry boundaries possible. It also led in some case to a rethinking of the meaning of resources. For example, two companies were experts in grinding in their respective industries. When one contracted work to the other though, they discovered that one of them was much cheaper than the other, a fact the companies could not have discovered through benchmarking only within their own industry. This discovery led to a revision in thinking about resources. Rather than viewing them as undifferentiated commodities, the view shifted instead to competencies: something one firm was better at doing than others. The second company was forced to reconsider its competencies, and determined that they lay in grinding smaller-sized parts and to more precise tolerances, which made them more expensive in that particular case, but able to do work that the other firm could not. In other words, in order to participate in the network, companies had to more clearly identify what competencies they could contribute.

Experiences of cooperative manufacturing also revealed services that were not linked to machine tools but which were equally important for successful projects. These capabilities were needed to back the network's competency to design and engineer complete customer solutions. Examples included assembly competency, quality inspection and testing capabilities, project management or certification for ISO conformity. These capabilities required complex combinations of information technology (for CAD, CAE), testing devices, skilled engineers or accreditation. Unlike simple machining operations, competencies discovered in this way are to a great extent intangible. There are no generally accepted definitions that can be used to describe the distinctive competencies the network could bring to bear on customer problems.

One important benefit of the project was that experiences within the project contributed to the further development of competencies within the partner firms. Companies faced requirements from a range of different industries and customer projects, which placed considerable stretch on their existing skills. Managers began to refer to this stretch as the "jogging effect", meaning that the little time they spent manufacturing for the network led to a greater increase in the fitness of the firm.

As well as within the individual member companies, competencies were developed at the level of the network as a whole. From experiences with joint manufacturing projects, stable sub-networks of partners emerged, which as a group proved to have competencies for applications, for example, in medical technology or precision machinery. In building these networks the Virtual Factory contributed to a trend of co-specialization of the partners. Some firms decided to give up certain technologies for which they found reliable partners in the network and to concentrate on other technologies which proved to be competitive over a wider range of industries.

In summary, the Virtual Factory project relied upon member firms' competencies, which are conceptualized as something one firm can do better than others. In order to contribute to the network, companies had to first clearly identify and further develop their competencies.

Phase II: Identification and facing of market opportunities

The Virtual Factory provided its member firms with market opportunities beyond their core businesses and industries, again as indicated symbolically by the grey boxes in Figure 1. The conception of identifying and facing market opportunities evolved through the course of the project. Initially, the understanding was simply market access, an important element in other networks where companies are not equally situated in terms of access to profitable opportunities. However, market opportunities do not present themselves neatly labelled as such. Instead, accommodating short-term market opportunities requires active entrepreneurial creation of business on the level of the partner firms as well as on the level of the network, which we refer to together as market facing.

Penrose [23, p. 31] argues that the market opportunity of a firm “comprises all productive possibilities that its ‘entrepreneurs’ see and can take advantage of”. Her central argument is that the growth of the firm is limited by the managerial services available for creating market opportunities. These services encompass competencies of the management team such as its “entrepreneurial versatility”, “fundraising ingenuity”, “ambition” or “entrepreneurial judgement”. Obviously, limits to entrepreneurial services exist particularly for the partners in the Virtual Factory, who are either internally-oriented production departments or small and medium sized firms, where highly specialized management re-sources are particularly scarce.

Explicit market facing took time to develop. The majority of manufacturing projects in the first two years of the project were carried out for customers from inside the network. Some manufacturing projects had served external customers, but these usually occurred by chance or were initiated by the customer. The research project worked nearly exclusively on how to organize work in the network, so market-facing was a matter for the individual partner firm. Experience and early success in manufacturing projects showed that the Virtual Factory was also successful with products that were not fully specified and for which the firms could use their engineering capabilities. To take advantage of these competencies, the project leaders promoted facing markets outside the network. Advances from the inward orientation to outside marketing were made in the third year of the action research project.

Organizational routines for facing market opportunities on the level of the network were initially developed as an adoption of existing product marketing techniques for the marketing of production competencies. For example, purchasing criteria were identified that could be used to signal the uniqueness and the buyer value of resources from the network. Mapping these purchasing criteria on market segments and customers resulted in a number of target segments for which sub-networks of firms developed marketing plans. Exposure to new business opportunities raised awareness of market facing among the managers involved. A saying became common among them: “Market opportunities are like trains that run again and again through the station. To catch the train, you have to practice jumping on trains, not construct new stations”.

In summary, identification of market opportunities provided member companies with access to applications for their manufacturing competencies in businesses beyond their traditional industry boundaries. Membership in the network exposed the firms to ideas and demands they would otherwise not have seen. Selecting business opportunities, as we have seen from the action interventions, requires more than simple picking them off the shelf. Instead, it is necessary for managers to be able and willing to perceive opportunities to stretch competencies beyond their primary business.

Phase III: Marshalling competencies

In the structure of the process theory, developing competencies and facing market opportunities represent two necessary preconditions in the network of firms. However, they are not in themselves sufficient to address a customer's need. Central to the success of projects in turbulent environments is the quick combination and recombination of the competencies necessary for a particular market opportunity. In order to meet this need, members of the Virtual Factory project developed routines for marshalling competencies, that is, to determine what competencies from which partner companies are required for a specific customer's request.

Again, the conception of marshalling evolved over the course of the project. Initial activities were based on literature suggesting that markets would be an efficient means of allocating resources to evolving market opportunities without hierarchical overhead or central management [24]. For example, Miles and Snow [25, 26] suggest that such market mechanisms will become more important for marshalling competencies with the use of information systems that reveal the status of potential trading partner (a full-disclosure system). A shift towards market coordination through computer systems also concurs with the predictions of transaction cost economics [27, 28]. In accordance with these suggestions, a full-disclosure information system, the so-called “Technology Capacity Bourse”, was developed in the early stages of the project. This database provided descriptions of the machine tools available in each of the member companies. The goal of the system was to reduce the cost of searching for partners and specifying competencies.

The system served its purpose until the partners attempted to include real-time capacity information to automate competencies marshalling. At that point, action reflection revealed that managers of the partner companies were not prepared to make decisions solely based on information from the database. This was especially true for many of the intangible competencies developed in the network that could not be described as succinctly and unambiguously as the physical resources (e.g., engineering or integration competencies). Because of the difficulty of describing such competencies, a simple database was out of the question in any case.

Instead of relying on technology, organizational routines for marshalling competencies had to be developed. The researchers analyzed early experiences of manufacturing projects to identify problematic situations. Small teams of managers and researchers then developed what the project partners called the “rules of the game”. Each rule was presented to all Virtual Factory partners and a formal vote taken on adding it to the set of guidelines for collaboration. These guidelines eventually covered the entire lifecycle of a co-operative manufacturing project and concerned for example how partners are selected, how prices are calculated co-operatively, a checklist of how to specify customer products, and a standard contract.

In addition, the researchers drew on literature to describe the complementary roles and positions of cooperating partners. Consideration of these functions led to the specification of a set of roles to ensure that the skills needed for a successful manufacturing project were provided. One firm might fill different roles (or even multiple roles) for different manufacturing projects, as long as it was clear who was responsible for each role and all were filled.

Apart from those explicit guidelines, mutual site visits and experiences from joint production projects contributed to shared knowledge about the competencies and priorities of individual partner firms in the network. This body of shared knowledge formed what some have called a knowledge market [29]. Frequent informal social contacts, such as the “virtual dinner" provided a business platform for marshalling competencies on a self-organized, *ad hoc* basis. Other authors have documented similar networks that seem to operate without a central design agency, such as industrial districts in Italy [10] and the film industry in Hollywood [30]. These cases are similarly reported to have culturally embedded restructuring mechanisms independent of any central institution.

Based on the mutual knowledge of partners' competencies that they had acquired during the project meetings and site visits, managers chose to use personal contact to directly settle technical issues. In fact, the database was regarded more as a means to establish a first contact (yellow pages), while placing orders was based on the personal contact, thus limiting the role of the database. Kumar, et al. [10] similarly report the failure of an information system for transaction management in the Prato region, which they attribute to a mismatch between the economic rationality of the system and the need of the managers to build trust and a relationship with the companies with whom they interacted.

Phase IV: Short-term cooperative effort

Rallying competencies requires that multiple partners temporarily unite to combine their forces in a concentrated effort to create a new solution for a customer. The fourth step in the process theory addresses the question of how management can facilitate and elicit "the willingness of individuals to contribute force to the cooperative system" [31, p.83]. There were several issues that had to be addressed.

Firstly, the project leaders had to address the development of cooperative processes to allow companies to give and take business at a reasonable cost. Evaluation of initial projects for customers from inside the project partners showed that the additional coordination among independent firms led to roughly 30% higher cost than would have been the case for a manufacturing project performed within a single firm. Firms therefore engaged in the reengineering of firm-boundary-spanning processes to make cooperation within the network as efficient as in-company processes, for which supply chain management techniques could be used [32]. Duplicate activities—such as repeated quality inspection each time a part crossed a firm’s boundary, filling out a full set of shipping papers and purchase orders, or work preparation and entering the workload in the next firm’s electronic planning systems—were traced and eliminated. Of course, elimination of these activities also removed an important set of safeguards against mistakes and opportunism by partners. For this type of cooperation to work, expectations for the performance of the work moved from control at the transaction level to controls at the level of the network, without, however, giving up the partners’ independence. Companies had to agree to follow the procedural guidelines that the project leaders derived from experiences with earlier manufacturing projects.

Second, direct communication was established between the involved operators in the Virtual Factory project, avoiding chain-of-command communication. For example, partner companies created dedicated liaison positions with the ability to by-pass normal business processes for network business or allowed an out-sourcing firm to contact machine operators directly. Consequently, expectations of what individual employees would do changed. For many operators, work for the Virtual Factory included external contact for the first time, forcing them to build skills in communication or conflict resolution. Of course, empowering production staff to accept work for the firm has the potential for conflict between their decisions and the traditional hierarchical control of the company and work processes.

Third, in the course of the project, short-term cooperation increasingly shifted towards substantial arrangements. The established guidelines, for example, covered the context of cooperation, e.g. the process of acceptance of new partners by the network, the process of specifying customer products, the process of calculation of cost, and the communication processes in the network. On the other hand, direct procedural arrangements to control transaction were declined by the partner firms. For example, after the discussion of several proposals, it was decided that a guideline for the allocation of resources within partner firms was not required. Instead, the managers agreed that work could be delegated within the network, but not the responsibility for its quality, timeliness and cost. In other words, rather than having a rule for how to allocate resources, it was the explicit agreement of the managers to leave open how commitments were met, as long as they were.

This focus on substantial rather than procedural cooperation resembles the particularities of the craft industrial mode. As Piore and Sabel [8] explain with the example of the construction industry, manufacturing projects are too short-lived, firms too unstable and employment too ephemeral for time-consuming process of grievance arbitration. Moreover, individual customer-defined projects vary too much to justify the establishment of arbitration systems which are unlikely to have any bearing on the facts of future conflict. Unlike mass production, this mode of working requires the collaboration between workers and managers. Since the work is always based on a unique design, problem-solving is a trial and error process based on the craftsman's experience. It is therefore not surprising that organizational units are small and supported by personal leadership. Improvements are based on the ingenuity and creativity of the individual and his technical excellence, which is challenged by the customer's desire.

Discussion

Two characteristics strike us as key to understanding the success of the Virtual Factory project, although further research would be valuable. A first characteristic is the nature of the product created in the network. The project started with the goal of trading commodity manufacturing, but it turned out that the network performed best for products requiring intensive engineering, for which intensive interaction between customer and designers and among designers is necessary. In short, the process summarized in Figure 1 worked best for cases where marshalling of competencies and cooperation mattered. On the other hand, for standard, off-the-shelf products, the degree of customized effort represented in this process is probably inappropriate. Instead, for these products an electronic market might be useful to lower transaction costs and enable customers to locate low-cost suppliers. A possible research question then is how companies can develop procurement processes and criteria to decide when to purchase from an electronic market and when to seek the specialized services of a Virtual Factory.

Secondly, the partners in the Virtual Factory project operate in turbulent environments, meaning that the environment, and in particular the demands of the market, changed more rapidly than the strategies and competencies of the companies can change. It was necessary for these companies to search for new market opportunities where they could apply their competencies and to be able to marshal collections of competencies, including competencies from other firms, in order to satisfy these market opportunities. Turbulence is characteristic of industries where market demand is uncertain or where technologies are rapidly evolving. Jones [33] have identified demand uncertainty, task complexity, human asset specificity and frequency as factors leading to the need for network governance. Describing Silicon Valley, Saxenian [34] showed how production networks among computer systems companies spread the risks of developing new technologies. Similarly, in the Hollywood film industry, agents provide access for actors to new films [35].

In a more stable environment, where innovation is less critical, some of the steps we have described may be unnecessary. For example, in Prato, where the production processes are well-understood, explicit marshalling of competencies seems to be less necessary.

Impannatore do not need to know the details of the production chain; instead, they pick an initial firm, which can in turn place further work. However, we speculate that even in stable environments the processes we have described may be useful. Miles and Snow [36] point out that dynamic networks—likely arenas for competencies rallying—offer firms additional strategic options. Competency rallying makes firms more agile, able to respond quickly to customer requests. Organizations that are practiced at the process we have described should be able to change very rapidly since they are constantly changing anyway. An important research question here is to identify and describe appropriate control mechanisms for firms that are constantly on the edge of instability.

Consideration of the case suggests that there are some important preconditions for its success, only some of which are fully understood and controlled by the project leadership. Many others were implicit in the industrial district, and created and reinforced by other means, such as common training, past interactions, etc. Other researchers have documented empirical evidence for such processes in industrial districts such as Prato [10] or the watch industry in Switzerland. In these areas, extensive socialization mechanisms have been developed, for example, professional schools, professional associations, institutions, governance structures and traditions [8]. In other words, while the manufacturing projects undertaken by the network are only short-term, commitment to the network and the industry is long-term. The failure of other networks may be attributable in part to an absence of these factors, which led to suspicion and mistrust among the partners, disinterest and eventual disintegration of the network [37].

Further research might consider what factors are necessary for the success of a cooperative venture such as the Virtual Factory project, and how these factors are realized. Many of these factors are regional and specific. Given that information technology makes cooperation possible on a global scale, future research might consider how (or indeed, if) absence of local factors can be overcome and cooperation extended globally.

Conclusion

In this paper, we developed a process theory of competency rallying, that is, of *the process of developing and bringing together in temporary cooperation a network of firms with the competencies needed to satisfy a newly-identified market opportunity*. Our theory hypothesizes that competency rallying consists of four related sets of organizational activities, specifically: 1) identification and development of distinctive competencies in network members, 2) identification and facing of short-term market opportunities, 3) marshalling competencies from network partners for a particular market opportunity and 4) a short-term cooperative effort. The basic building blocks of our process theory have been discussed before, but our theory is novel in the way that it weaves together an external perspective on market-facing with an internal perspective on competency development and marshalling to describe the overall process of competency rallying.

The purpose of an action research study such as the one reported here is to guide and inspire new ideas and practices rather than systematically testing existing theories. Our theory of competency rallying suggests that performance of firms in turbulent environments should be studied by considering both how these firms face the novel market opportunities and how they marshal competencies to attack these opportunities. Study of these rallying processes generalizes the concept of agility beyond its origins in the reallocation of mainly physical resources. Competency rallying offers a perspective on sustainable firm performance based on the mastering of organizational routines of change rather than static positions of competitive advantage.

Competency rallying

The extent to which our local explanation of competency rallying in turbulent environments, summarized in Figure 1, develops into a more general theory depends on how well it works in other settings. One of the first questions for future research is whether or not the process of competency rallying in other settings resembles our model, or whether the model is unique to the Virtual Factory project. One approach to answering this question is to apply well-known theory-testing techniques. For example, a large-scale survey of networks could be attempted to statistically replicate this model. A problem with this approach is the difficulty of identifying functioning networks, since unlike firms, they do not appear in directories with contact addresses, ready to be sampled. Another approach would be a meta-analysis of existing case descriptions of networks, although there are obvious difficulties with this approach also.

For an action research project, it may be more meaningful to ask how the experiences of this project can influence further action. In this sense, replication of the Virtual Factory project is already underway, as other groups are building similar networks in their own regions and industries. One such example can be found in the construction industry in Switzerland. Four other networks in precision machining are operating or planned in the regions around Bern and Basel, Switzerland and Augsburg and Aachen, Germany. One of these groups has already informally reported a significant backlog of orders for the network. These groups have adopted the Virtual Factory processes and, though independent, are working with the Virtual Factory research team. Clearly, the interest of these groups in replicating the Virtual Factory project is an indication of its success in changing peoples' mindsets about the value of such cooperative networks. Their experiences will be a valuable replication of our results.

References

[1] J. Bain, *Industrial Organization.* New York: Wiley & Sons, 1959.

[2] A. D. Chandler, Jr., *Strategy and Structure: Chapters in the History of the American Industrial Enterprise*. Cambridge, MA: MIT Press, 1962.

[3] B. Wernerfeld, “A resource-based view of the firm,” *Strategic Management Journal*, vol. 5, pp. 171-180, 1984.

[4] C. K. Prahalad and G. Hamel, “The core competence of the corporation,” *Harvard Business Review*, vol. 68, pp. 79-91, 1990.

[5] H. Mintzberg, “Patterns in strategy formulation,” *International Studies of Management and Organization*, vol. 9, pp. 67-86, 1979.

[6] M. S. Poole and A. van de Ven, “Using paradox to build management and organization theories,” *Academy of Management Review*, vol. 14, pp. 562-578, 1989.

[7] British Academy, *The Oxford English Dictionary*. Oxford: Oxford University Press, 1971.

[8] M. J. Piore and C. F. Sabel, *The Second Industrial Divide - Possibilities for Prosperity*. USA: Basic Books, 1984.

[9] E. Ritaine, “Prato: An extreme case of diffuse industrialization,” *International Studies of Management and Organization*, vol. 20, pp. 61-76, 1990.

[10] K. Kumar, H. G. van Dissel, and P. Bielle, “The Merchant of Prato revisited: Towards a third rationality of information systems,” *Management Information Systems Quarterly*, pp. 1-37, 1996.

[11] K. E. Weick, *The Social Psychology of Organizing.* Reading, MA: Addison-Wesley, 1969.

[12] K. Lewin, *Feldtheorie in den Sozialwissenschaften.* Bern: Haupt, 1963.

[13] G. I. Susman and R. D. Evered, “An assessment of the scientific merits of action research,” *Administrative Science Quarterly*, vol. 23, pp. 582-603, 1978.

[14] A. Rapaport, “Die wissenschaftlichen und methodischen Grundlagen der allgemeinen Systemtheorie,” in *Integriertes Management - Bausteine des systemorientierten Managements*, G. J. B. Probst and H. Siegwart, Eds. Bern: Haupt, 1985, pp. 147-163.

[15] H. Aguinis, “Action research and scientific method: Presumed discrepancies and actual similarities,” *Journal of Applied Behavioural Science*, vol. 29, pp. 416-431, 1994.

[16] F. Friedlander and D. Brown, “Organization development,” *Annual Review of Psychology*, vol. 25, pp. 313-341, 1974.

[17] R. L. Baskerville and A. T. Wood-Harper, “A critical perspective on action research as a method for information systems research,” *Journal of Information Technology*, vol. 11, pp. 235-246, 1996.

[18] G. Schuh, K. Millarg, and A. Göransson, *Die Virtual Factory.* Stuttgart: Hanser Verlag, 1998.

[19] L. B. Mohr, *Explaining Organizational Behavior: The Limits and Possibilities of Theory and Research*. San Francisco: Jossey-Bass, 1982.

[20] M. H. Meyer, “The product family and the dynamics of core capabilities,” *Sloan Management Review*, vol. 34, pp. 29-47, 1993.

[21] K. Miyazaki, *Building Competencies in the Firm: Lessons Learned form Japanese and European Optoelectronics*. New York: MacMillan, 1995.

[22] M. H. Meyer, P. Terzakian, and J. M. Utterback, “Metrics for managing research and development in the context of the product family,” *Management Science*, vol. 43, pp. 88-111, 1997.

[23] E. Penrose, *The Growth of the Firm*. Oxford: Basil Blackwell, 1968.

[24] L. S. Flaig, “The “virtual enterprise”: Your new model for success,” *Electronic Business*, pp. 153-155, 1993.

[25] R. E. Miles and C. C. Snow, “Organizations: New concepts for new forms,” *California Management Review*, vol. 28, pp. 62-73, 1986.

[26] R. E. Miles and C. C. Snow, “Network Organizations: New Concepts for New Forms,” *The McKinsey Quarterly*, pp. 53-66, 1986.

[27] O. E. Williamson, *Markets and Hierarchies: Analysis and Antitrust Implications. A Study in the Economics of Internal Organization.* New York: Free Press, 1975.

[28] T. W. Malone, J. Yates, and R. I. Benjamin, “Electronic markets and electronic hierarchies,” *Communications of the ACM*, vol. 30, pp. 484–497, 1987.

[29] T. H. Davenport and L. Prusak, *Working Knowledge : How Organizations Manage What They Know*. Boston: Harvard Business School Press, 1997.

[30] H. T. Goranson, M. Fox, B. R. Katzy, T. Williams, and D. Wisnosky, “Human factors and enterprise integration,” presented at ICEIMT ´97, Washington, Turin, 1997.

[31] C. I. Barnard, *The Functions of the Executive*. Cambridge, MA: Harvard University, 1964.

[32] M. Christopher, *Logistics and Supply Chain Management - Strategies for Reducing Costs and Improving Services*. London: Pitman, 1992.

[33] C. Jones, W. S. Hesterly, and S. P. Borgatti, “A general theory of network governance: Exchange conditions and social mechanisms,” *Academy of Management Review*, vol. 22, pp. 911-945, 1997.

[34] A. Saxenian, “The origins and dynamics of production networks in Silicon Valley,” *Research Policy*, vol. 20, pp. 423-437, 1991.

[35] H. T. Goranson, “Agility Measures: Engineering Agile Systems,” : http://www.agilityforum.org/Ex_Proj/MAVE/mave.html, 1997.

[36] R. E. Miles and C. C. Snow, “Causes of failure in network organizations,” *California Management Review*, vol. 34, pp. 53-71, 1992.

[37] S. E. Human and K. G. Provan, “An emerging theory of structure and outcomes in small-firm strategic manufacturing networks,” *Academy of Management Journal*, vol. 40, pp. 368-403, 1997.

Figures and Tables

Table 1. Examples of manufacturing projects worked on by the Virtual Factory.

Manufacturing Project	**Description of Product**	**Description of competency rallying**
1 Mechanism to electrically retract a car steering wheel	The mechanism targets a market of less than 10.000 items a year and is therefore not interesting to auto suppliers used to lot sizes of hundreds of thousands. It is technically challenging, as it has to meet safety standards of auto industry at competitive manufacturing cost.	The network was prepared to face such opportunities, responding within two days to the customer request To marshal the best competencies, ten potential technologies were identified. In a co-operative effort with the customer engineering changes were implemented and prototypes manufactured.
2 Large precision base for tool machine	The base was a 20-mm sheet metal, roughly 1m x 1.5-m in size. More than 300 holes were needed for the assembly of all mechanisms of the tool machine. Placement of the holes defined the machine's precision. The piece was too big for most machines.	Alternative technologies such as drilling, laser drilling, and water drilling were identified and compared. Marshalling of a large dimension tool machine, on which the piece could be machined in one fixing. Value created was quality improvement (because of one fixing), and 75 % cost reduction.
3 Module for a letter sorting machine	The manufacturing of a module of an industrial postal letter sorting machines that was fully engineered. To meet short delivery deadlines, the manufacturer needed additional manufacturing capacity. The module was structured in mechanical and electrical subassemblies, and painted sheet metal as the cover and stand.	Competencies from the network. E.g. controller manufacturing for textile machines, and sheet metal manufacturing and painting from furniture industry were marshaled for the customer project. A short-term co-operative effort undertaken with the customer to achieve a frictionless integration of mechanical and electrical subsystems of the module.

Table 1, continued.

Manufacturing Project	**Description of Product**	**Description of competency rallying**
4 Air-conditioning unit	The concept of an air-conditioning unit, fitting a demand pocket in the upper range of the market was engineered and manufactured as a project lasting about two years.	During a presentation of the Virtual Factory project an engineer in the audience revealed having a product concept and asked the necessary competencies to be marshaled from the network. On stage, project members analyzed the idea and proposed an initial architecture of contributions from three partners. Business was agreed, in a cooperative effort with the customer the unit was engineered, prototyped and 50 copies manufactured after 18 month, further orders are pending.
5 Fifteen end of life-cycle industrial products such as slides, fans, necks and nozzles	At the beginning of the project, old, simple to manufacture and fully specified products with a low known annual demand were given to the network, because these were assumed to best fit a spot market for idle capacity.	The products were partially successful where direct cost effects were achievable with resources better fitting the manufacturing task. Due to already assumed learning effects in the long life cycle, effects however remained small. Indirect effects were observed where outsourcing opened disinvestment opportunities of constantly underutilized resources.
6 Re-engineering stability of a large sun-umbrella	Finite element simulation competency of an engineering firm in the network was used to improve wind stability of large restaurant umbrellas marketed by a textile manufacturer.	The network was prepared to face market opportunities from outside its companies' core-businesses. The network's brokers channeled a customer request from textile industry to highly specialized competencies available in a firm from the mechanical industry.